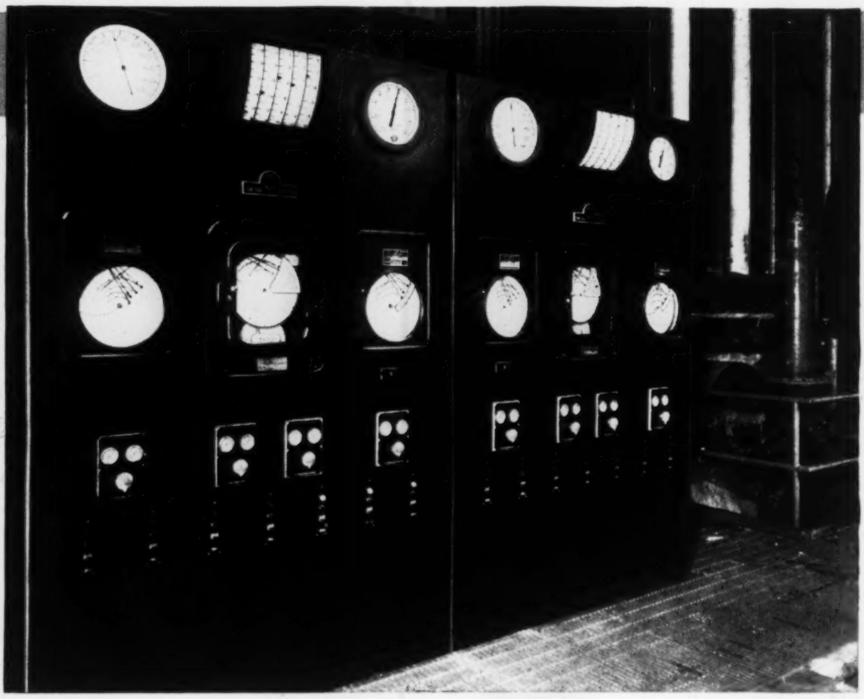
MECHANICAL ENGINEERING

September 1935



Individual boiler control panels including metering equipment and COMPLETE combustion control for two pulverized coal fired boilers.

WHEN YOU MODERNIZE

include COMPLETE *Combustion Control for Continuous Test Results*

COMPLETE CONTROL AUTOMATICALLY

1 Maintains desired steam pressure.

2 Maintains most economical fuel-air ratio.

3 Maintains desired furnace draft.

Your modernization program is not complete until you provide for the continuous operation of your new equipment at test efficiencies. Bailey Meter Control produces these test results because it is COMPLETE.

It not only maintains steam pressure but also automatically readjusts fuel or air to constantly maintain maximum combustion economy. Constant control of fuel-air ratio and the accurate control of furnace draft reduces furnace maintenance to a minimum.

The new Bailey Air-Operated Control is described in Bulletin No. 102. Send for your copy today.

BAILEY METER CONTROL SYSTEM

Bailey Products

BOILER METERS
COMBUSTION CONTROL
MULTI-POINTER GAGES
FEED WATER CONTROL
SMOKE DENSITY RECORDERS
FLUID METERS
PYROMETERS
RECORDERS

BAILEY METER COMPANY
1026 IVANHOE ROAD • CLEVELAND, OHIO
Bailey Meter Company Limited, Montreal, Canada

A-7

BAILEY METER CONTROL

The COMPLETE *Combustion Control System*

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 9

Contents for September, 1935

CONSTRUCTION OF 115,000-HP BOULDER DAM TURBINES . *W. M. White* 539
THE DIESEL ENGINE FOR RAIL TRANSPORTATION . . . *John Dickson* 547
"THE COMET"—HIGH-SPEED TRAIN (PART II) . . . *Karl Arnstein* 553
SALVAGE AND RECLAMATION . . . . *T. H. Owens* 561
PREVENTION OF WASTE AND RECLAMATION OF MATERIALS *J. Q. Salisbury* 563
A LUBRICATION PROGRAM . . . *V. M. Palmer and H. F. Smith* 565
PREFABRICATED HOUSING 571
THE PASSAMAQUODDY TIDAL-POWER PROJECT 580
INTERNAL DEBT AND LIQUID CLAIMS TO WEALTH . *Olin Ingraham* 582

EDITORIAL 537
ENGINEERING PROGRESS 584
LETTERS AND COMMENT 592
A.S.M.E. BOILER CODE 598
REVIEWS OF BOOKS 599
WHAT'S GOING ON 603

DISPLAY ADVERTISEMENTS 1
WHAT'S NEW 12
PROFESSIONAL SERVICE 27
CLASSIFIED ADVERTISEMENTS . . . 28
INDEX TO ADVERTISERS 30

OFFICERS OF THE SOCIETY:

RALPH E. FLANDERS, *President*
ERIK OBERG, *Treasurer* C. E. DAVIES, *Secretary*

PUBLICATION STAFF:

GEORGE A. STETSON, *Editor* FREDERICK LASK, *Advertising Mgr.*

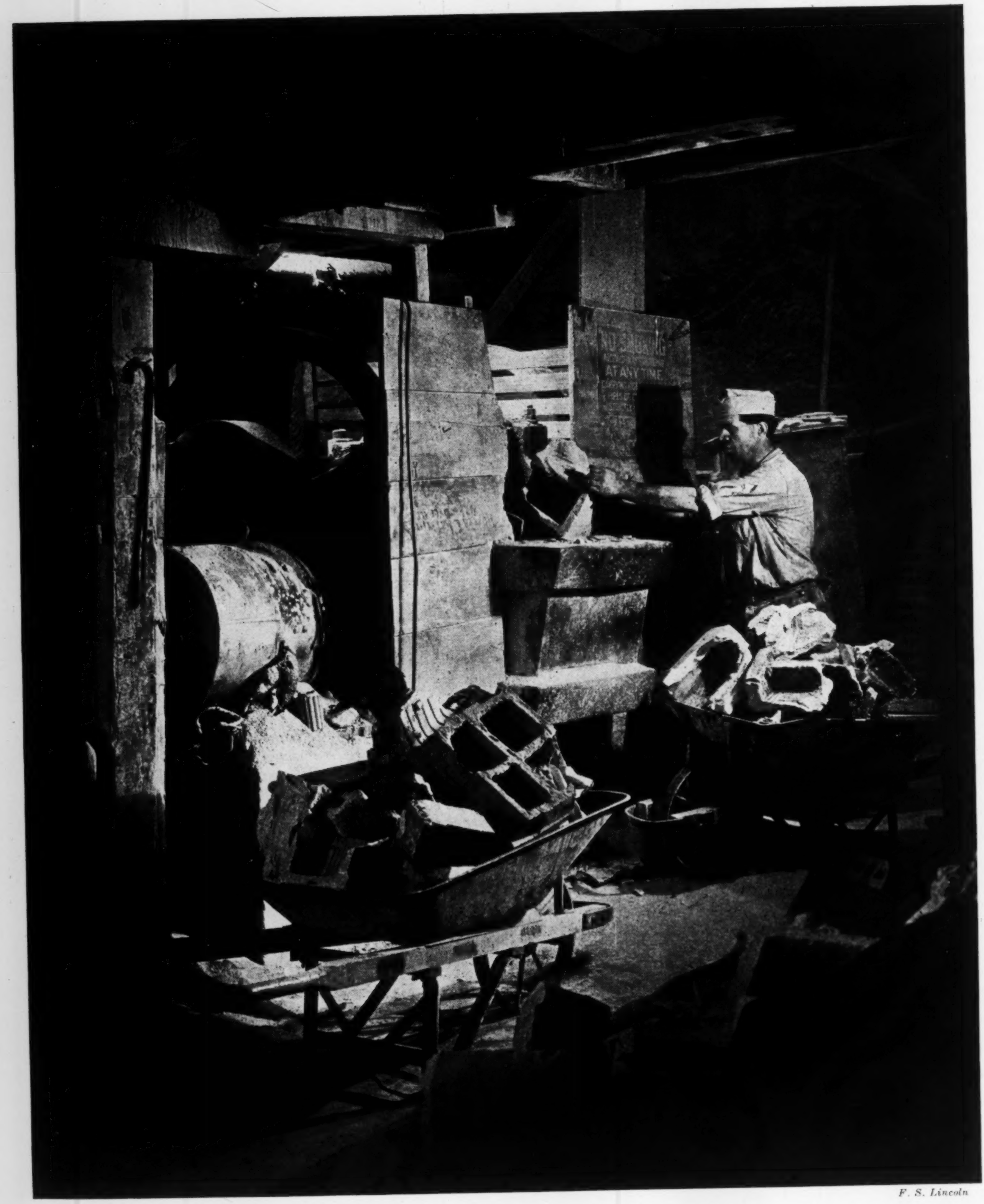
COMMITTEE ON PUBLICATIONS:

S. W. DUDLEY, *Chairman*
S. F. VOORHEES W. F. RYAN
G. F. BATEMAN M. H. ROBERTS

ADVISORY MEMBERS OF THE COMMITTEE ON PUBLICATIONS:

E. L. OHLE, ST. LOUIS, MO. E. B. NORRIS, BLACKSBURG, VA. A. J. DICKIE, SAN FRANCISCO, CAL.
Junior Member, O. B. SCHIER, 2D

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted, 1935, by The American Society of Mechanical Engineers.


NO SMOKING
AT ANY TIME

F. S. Lincoln

Men and Machines—The Clay Products Industry

VOLUME 57
No. 9

MECHANICAL ENGINEERING

SEPTEMBER
1935

GEORGE A. STETSON, *Editor*

"Blind Landings"

FOLLOWERS of the news were gratified to read that on July 22 President Roosevelt presented the Collier Trophy to Capt. Albert F. Hegenberger for his contributions to airplane flying by instruments and for having carried his experiments to the point where he has been able to land "blind." This is acknowledged an achievement of great significance to aerial navigation and a notable advance in safety in flight.

Captain Hegenberger was on the program of the A.S.M.E. Semi-Annual Meeting at Cincinnati, Ohio, with an address with the suggestive title, "Blind Landings." Circumstances prevented his delivering the address, but Elmer Sperry filled the breach most acceptably, and revealed to those who heard him the amazing advances that have been made in this important branch of aviation. Land-bound creatures were convinced that real progress is being made in the fight against one of the greatest uncertainties in this new and rapidly growing field of transportation.

Flights of transport planes between California and Hawaii have inspired confidence in our ability to reach a distant objective with reasonable certainty, and if the landings, amid adverse weather conditions frequently prevailing in the vicinity of airports, can be made "blind" with safety, a great handicap to air travel will have been appreciably reduced. Congratulations to Captain Hegenberger and all those who are working in this branch of aeronautical development—not forgetting the instrument makers without whose foresight, initiative, and cooperation the efforts of experimenters would be futile.

Personal Records

WITH the August issue of the Transactions of The American Society of Mechanical Engineers there was mailed as a supplement Part 2 of the Society Records which contains the memorial notices of deceased members. Those whose connection with the Society covered any considerable portion of the last quarter century will find this publication of more than usual interest because it contains a biography and portrait of Secretary Calvin W. Rice whose sudden death less than a year ago brought to a close a life of service to engineering. Excerpts from Doctor Finley's address on Doctor Rice, delivered at last year's annual meeting but hitherto unpublished, accompany the biographical sketch, as does also the tribute of a special committee of Council.

The publication of these memorial notices provides an opportunity to direct attention to the work of the Society's Committee on Publications in placing on record the achievements of deceased members. In the opinion of the Committee it is an important obligation of the Society to make these records as complete and as worthy of the memories of loyal members as reasonable care and a sympathetic understanding of human values will permit. The task of assembling the essential facts for these notices, brief as many of them may seem, is not simple.

Most of us lead singularly unspectacular lives. We do not, as a rule, have occasion to come frequently to the attention of our fellows to the extent that the press of the nation makes extensive note of our achievements. Even in the organizations to which the greater part of our efforts are devoted pay scant attention to a year-by-year record of our services to them. And when death comes suddenly, or after retirement, it too often happens that authoritative and frequently important information is forgotten or utterly lacking. Hence there lies upon each of us the duty of assisting in assembling such data as are important and of supplying to those whose responsibility it is to prepare the permanent record with as many appreciations and interpretations of the lives and services of our deceased associates as possible.

Placing on record the services of deceased members to the profession of engineering is one of the most obvious evidences of appreciation that a Society can show. To whom shall the profession and the world look to perform this service if not to the Society, loyally supported during his lifetime by the individual whose work is done? In maintaining a high standard of authoritativeness, completeness, and understanding in these records every member can assist by devoting time and thought to requests for information that may come to him from the Committee on Publications. To those who have given such assistance in the past, the Committee is profoundly grateful.

Helping Junior Members

SPEAKING before the Kansas City section of The American Society of Mechanical Engineers in May, 1935, on the "General Impressions of a Junior Engineer," Theo. A. Tobin, Junior, A.S.M.E., made some points that the Society's interest in its younger members will serve as an excuse to repeat.

Mr. Tobin, alive to the idealistic and often romantic views of the engineering profession and engineers held by students in engineering schools, pointed to the rude awakenings that are sometimes unavoidable and often needlessly unfortunate. He called his older hearers to task, for example, for making a bad impression before audiences of students because of sloppiness in appearance and in public address. The man of great deeds frequently is too human and ordinary an individual as compared with what his achievements have led youngsters to expect in him.

As the young critic took pains to point out, disillusionment in the anticipated superman is a natural and necessary step in contacts with reality, and the youth himself is as much to blame as any one in expecting the impossible and in forming superficial judgments from unfavorable appearances. Mr. Tobin then asked how the young student can be brought "down to earth" more graciously. Here, in his opinion, responsibility rests on the older men whom he took to task for having "failed miserably." His plea was that more consideration be given by men in the profession to the youth who is attempting to find a place in it.

Undoubtedly there will be differences of opinion among engineers as to the validity of this criticism. Many will refuse to acknowledge the failure with which they are charged and others will deny any large measure of responsibility. Some will question whether their own achievements would have been as great if their paths had early been made easy. But a majority will agree in principle that there is more to be gained than lost in a sympathetic understanding of a young man's difficulties and perplexities.

The E.C.P.D. is giving much study to this subject and has sought to encourage engineers in local sections of the engineering societies in devoting attention to the affairs and problems of recent graduates. Contacts with younger men will prove interesting and stimulating to many engineers and enthusiasm for this form of post-collegiate guidance develops naturally when the satisfactions that come from worth-while endeavor are realized. The American Society of Mechanical Engineers is urging its older members to form these contacts in their own communities, confident that the results will be a better profession and a better society. Proof will depend upon the manner in which engineers respond to opportunities that are presented to them to get into this work. It is worth trying.

Engineers' Interest in Noise

THE recent announcement that Mayor La Guardia intends to make New York follow the example of its rival metropolis London in doing something about city noises recalls some of our former fulminations against this annoying concomitant of advancing civilizations in congested areas. In the two great aspects of this problem, noise elimination and noise abatement, engineers have peculiar opportunities for service.

Fundamentally, it is from the the contributions of engineering that most of the noise arises. An increasing number of mechanical contrivances results in more noise and new noises from new sources. Transportation agencies, trains, street cars, automobiles, and now the airplane are noteworthy examples. The infrequent whistle and clank of the locomotive is a gladsome sound in a remote rural setting for it gives us a contact with the outer world that is reassuring, but in urban communities the ceaseless roar and discordant confusion of mechanical sounds descend to the level of common nuisances.

Engineers and the transportation industries are not unmindful of this. "Quiet" and "silent" street cars and subway trains are being introduced. In particular, the extending use of rubber is making welcome contributions in this direction. Doctor Arnstein, for example, mentions the use of rubber in the construction of the high-speed train, *The Comet*, in this issue. C. F. Hirshfeld and the engineers working with him in the design of a modern trolley car that is plying the streets of Brooklyn in increasing numbers are said to have eliminated practically all of the noises customarily associated with this notorious offender, with such success that the wheel on the trolley wire is now heard above the other lost or muted sounds. One of the richest blessings of air conditioning is the shut windows that exclude a portion at least of external noise from trains and buildings. And in the field of noise abatement enterprising engineers and industries are offering sound-absorbing and sound-deadening materials for building construction. A harassed world is grateful to these easers of din.

Upon the designers and manufacturers of machines and mechanical devices an especial responsibility rests to remain unsatisfied with their work unless attention has been directed to noise-elimination features. Some time ago we urged that no designer should be satisfied with his product unless he has given careful consideration to its safety features. The same consideration should be given to noise elimination. A machine should be considered imperfectly designed unless every reasonable attempt has been made to make it as noiseless as possible, and to remove from it features that offer a temptation to the thoughtless, or the perverse, to raise din and clatter with it.

The problem is not easy. To many it seems trivial. Thankful enough is the aspiring inventor if his machine runs, and the noise of its dynamic being is frequently music to his ears. But efforts toward development and perfection are incomplete unless some attempt to hush its infantile cries is made. Some one should see to that.

As in smoke abatement, eternal vigilance will be necessary if noises from mechanical contrivances are to be kept in check. The most quiet machine, in thoughtless and inept hands, can soon become a nuisance. And practical considerations of cost must also be met. People must be willing to pay the price of a noiseless city, just as they must be willing to pay the price for a smokeless one. But if engineers are able to show that the thing is possible and reasonable, perhaps city dwellers will find it worth while.

The Construction of the 115,000-HP *Boulder Dam* TURBINES

By W. M. WHITE

ALLIS-CHALMERS MANUFACTURING COMPANY

THE BOULDER DAM is now stopping flow of water from the drainage area west of the peaks of the Rocky Mountains beyond Denver, from the southern half of Montana, from the eastern part of Utah, and from the northwestern corner of New Mexico. The waters of the Green River, the Colorado River, the Gunnison River, the Dolores River, and the San Juan River are now filling the Boulder Dam reservoir. The depth of the water in the reservoir is now (May, 1935) about 150 ft and its color is already changing from yellow to green. It is expected that it will take three or four years for the flow from this drainage area to fill the reservoir and supply the water which must be passed during this time.

The Act of Congress providing for the construction of Boulder Dam sets forth the objects sought in order of their importance, as follows:

(*a*) The regulation of the Colorado
(*b*) The storage of water for irrigation
(*c*) Supply water for cities and manufacturing plants
(*d*) Development of power with which to repay the cost of construction.

To accomplish these prime purposes for which Boulder Dam is being built, the height of the lake will necessarily be controlled with little reference to the maintenance of a head most suitable for any hydraulic turbines. Each year about the first of May, the level of the water must be low enough to provide sufficient reservoir capacity to catch the spring floods caused by the melting snows in order that there may be regulation of the Colorado. At other times, sufficient water must be passed through either the turbines or by-pass needle valves to meet the requirements of irrigation and water supply below the dam. The hydraulic turbines, therefore, had to be designed to operate throughout the year under varying heads from a minimum of probably 420 ft to a maximum of 590 ft.

TABLE 1 COMPARISON OF LARGE HYDRAULIC TURBINES

Development	Manufacturer	Horse-power	Head, ft	Rpm	Specific speed	Approx. runner diam	Began operation
Boulder Dam	Allis-Chalmers	115,000	420 590	180	27	14′3″	Under const.
Niagara	Allis-Chalmers (One Unit)	84,000	213	107	35	15′4″	1925
Conowingo	Allis-Chalmers (Four Units)	54,000	89	81.8	70.0	17′9″	1928
Martin Dam	Allis-Chalmers (Two Units)	50,000	150	120	51	12′7″	1927
Osage	Allis-Chalmers (Six Units)	33,500	90	112.5	75	14′5″	1931
Dnieprostroy	Newport News	100,000	123	88.2	68	19′10$^1/_2$″	1932
Muscle Shoals	Newport News	35,000	92	100	66.0	15′6″	1926
Beauharnois	Dominion Engineering	53,000	80	75	72	19′0″	1932
Diablo	S. Morgan Smith	90,700	327	171.5	37		Under const.
Isle Maligne	Can. Allis-Chalmers	45,000	110	112.5	67	14′0″	1925–1930
Abitibi	Can. Allis-Chalmers	66,000	237	150	41	11′4″	1934
Chute Caron	Morgan Smith-Inglis	75,600	165	120	56	13′0″	1931
Queenston	I. P. Morris	58,000	294	187.5	37	10′6″	1922–1930
Cardano—Italy		45,000	509	300	26	8′4″	1929
Galleto—Italy		50,000	646	300	21	8′2″	1930
Oak Grove	Pelton	40,000	850	514	22	6′1″	1925-1930

The Colorado River carries 137,000 acre-feet of silt per year. It is expected that the river channel below Boulder Dam will be washed out, lowering the level of the tail water possibly 25 ft in ten or fifteen years. To provide for this eventuality and to keep the ultimate suction head within safe limits, the turbines are set 10 ft below the now expected normal tail-water level and 29 ft below the now expected maximum tail-water level.

The size of the turbines was fixed by the desire to have the very maximum-capacity turbines that could be economically constructed and transported; also, it was desired to have the runner cast in one piece because of the high head and terrific stress to which it would be subjected. These considerations led to the selection of 15 units each 115,000 hp capacity and two units each 55,000 hp capacity. The units are to develop full capacity at about 475-ft head. If the entire average annual flow of water could be passed through the turbines, there would be sufficient water to operate about 12 units continuously at their most efficient point.

If the large turbines could be operated under wide-open gate under the head of 590 ft, they would develop 158,000 hp. The size of the generators, however, limits the output of the turbines to about 115,000 hp and it will be necessary to limit the turbine gate opening under the higher heads. The turbines are guaranteed to develop 90,000 hp under an operating head of 420 ft. The speed is 180 rpm. A comparison of the size of these turbines with others in operation may be gained from Table 1.

Although the power houses are constructed adjacent to the dam, the size and thickness of the dam, length of the power house, and location of the towers for taking in water for the penstocks are such that there are relatively long water columns, necessitating ample strength in the design of all parts to resist possible water hammer.

As an additional safeguard, a pressure regulator is provided with each turbine, having a discharge capacity of 80 per cent of that of the turbines.

The quantity of water to be used by the turbine is such that it was necessary to make the intake of the spiral casing 10 ft

---

Contributed by the Hydraulic Division and presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 17–21, 1935, of The American Society of Mechanical Engineers.

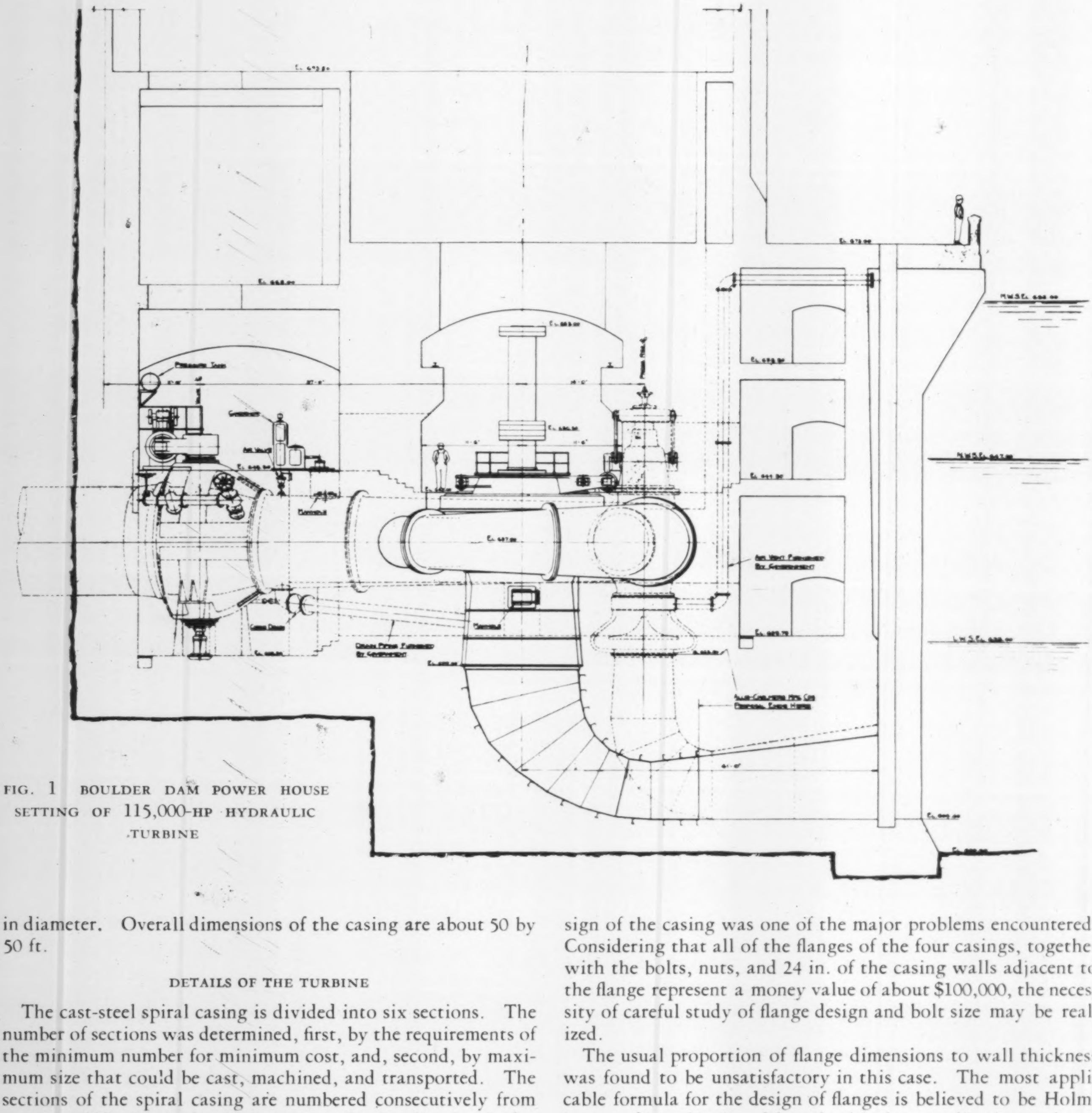


FIG. 1 BOULDER DAM POWER HOUSE SETTING OF 115,000-HP HYDRAULIC TURBINE

in diameter. Overall dimensions of the casing are about 50 by 50 ft.

DETAILS OF THE TURBINE

The cast-steel spiral casing is divided into six sections. The number of sections was determined, first, by the requirements of the minimum number for minimum cost, and, second, by maximum size that could be cast, machined, and transported. The sections of the spiral casing are numbered consecutively from one to six, No. 1 being at the entrance. Section No. 2 embodying the nozzle outlet for the pressure regulator weighs approximately 100,000 lb. The total weight of the six sections is about 450,000 lb.

The specifications require that the casings be tested in the shop under a hydrostatic pressure range from 0 to 500 lb per sq in. The specifications provide certain definite allowable design stresses from which was determined a thickness of cast-steel casing wall of 3 in. at the entrance to the spiral.

From three to five stay vanes in each of the six sections were sufficient to tie the inner ends of the sections and these 24 stay vanes naturally led to the adoption of 24 guide vanes, since that number is sufficient to give smooth flow of water to the runner and not to increase the cost unreasonably.

On account of the high head and high test pressure, the design of the casing was one of the major problems encountered. Considering that all of the flanges of the four casings, together with the bolts, nuts, and 24 in. of the casing walls adjacent to the flange represent a money value of about $100,000, the necessity of careful study of flange design and bolt size may be realized.

The usual proportion of flange dimensions to wall thickness was found to be unsatisfactory in this case. The most applicable formula for the design of flanges is believed to be Holmberg and Axelson's, although this has application only to flanges on straight cylindrical pipes. The proportion of flanges, size, and material of the bolts adopted in the design of this casing were the direct result of a series of special tests.

The power-house setting of the unit is shown in Fig. 1.

A cross-section in elevation, Fig. 2, shows the details of the turbine to be typical of the usual high-head turbine incorporating cast-steel guide vanes with cast integral stems, specially designed cast-steel levers with breaking pins, cast-steel shifting ring, cast-steel cover plate in halves, cast-steel extension section for supporting the cast-steel shifting ring, and the cast-iron, babbitted, oil-lubricated bearing.

The 38-in. diameter shaft with $64^3/_4$-in. diameter flanges is made in two sections. The power house has been designed and a crane placed underneath the generator so that the upper sec-

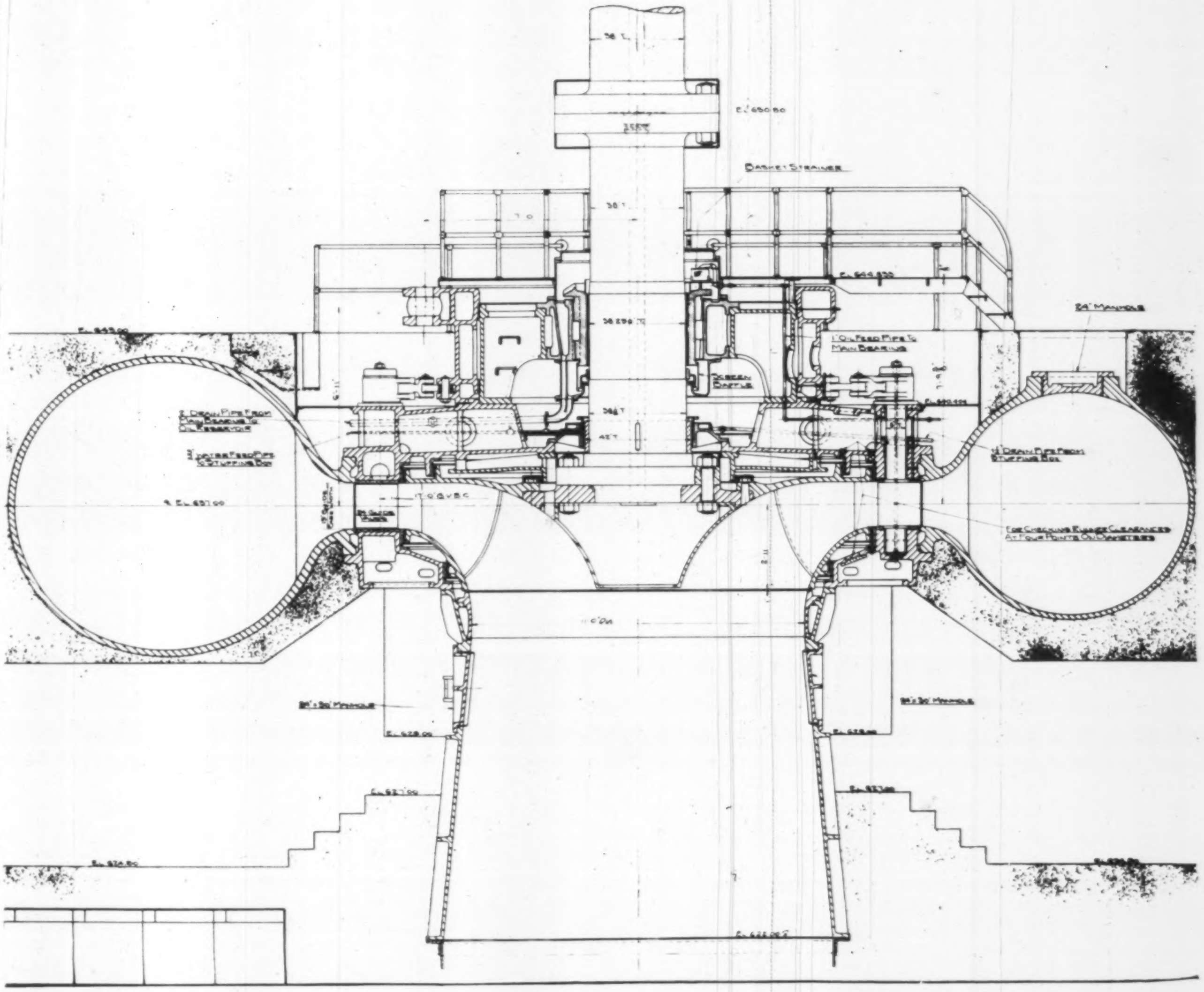

Basket Strainer
E. 650.80
1" Oil Feed Pipe to Main Bearing
Screen Baffle
24" Manhole
Drain Pipe From Main Bearing to Oil Reservoir
Water Feed Pipe to Stuffing Box
Drain Pipe From Stuffing Box
For Checking Runner Clearances At Four Points On Diameters
El. 637.00
24" x 30" Manhole
El. 628.00

FIG. 2 CROSS-SECTION OF BOULDER DAM 115,000-HP HYDRAULIC TURBINE

tion of the turbine shaft may be removed, after which the remaining parts of the turbine may be removed without disturbing the generator. On account of the large size of the turbine, the cover-plate extension is sufficiently large, so that ingress is possible for adjusting a stuffing box around the turbine shaft. A good stuffing box is necessary because the tail water during the first years of operation may be about 25 ft above the center line of the turbine.

On account of the low specific speed of the runner, leakage through the runner clearances is a much larger proportion of the total discharge than on high-specific-speed turbines, so that special care has been taken to minimize this leakage. This is accomplished first by providing two sets of wearing rings on both top and bottom of the runner. Labyrinth wearing rings were not desirable as it was thought that the friction of the greater surface would more than off-set the claimed saving in leakage; in fact, the Government specifications prohibited the use of labyrinth rings.

The material of the stationary rings is stainless steel and the material in the rings of the runner is S.A.E.-1035. The bore in the cover plate and discharge ring for the stationary rings has been bored $^1/_{16}$ in. smaller than drawing dimension. A grinding device is supplied by which the seats for these rings will be machined and ground to exact concentric dimensions after the bearing has been erected and the guide bearing fitted in place.

A removable cast-steel throat ring has been provided just below the runner and may be renewed in case of serious pitting on this portion, which is near the discharge from the runner vanes.

A stainless-steel sleeve, made in halves, is held on the shaft in the stuffing box by means of special H-keys running the whole length of the bushing. Renewable facing plates have been fastened to the face of the cover plate and discharge ring along the faces of the movable guide vanes.

The upper section of the draft tube is made of cast steel in six sections. The lower section of the draft tube is made of $^3/_4$-in. plate steel welded.

A plan view, Fig. 3, shows the relation of the spiral casing, pressure regulator, and operating cylinders. The piston rod of one of the operating cylinders extends through the cylinder head and has an adjustable nut mounted upon it providing for the limiting of the open position of the guide vanes. This limit is used because of the extremely wide variations in head

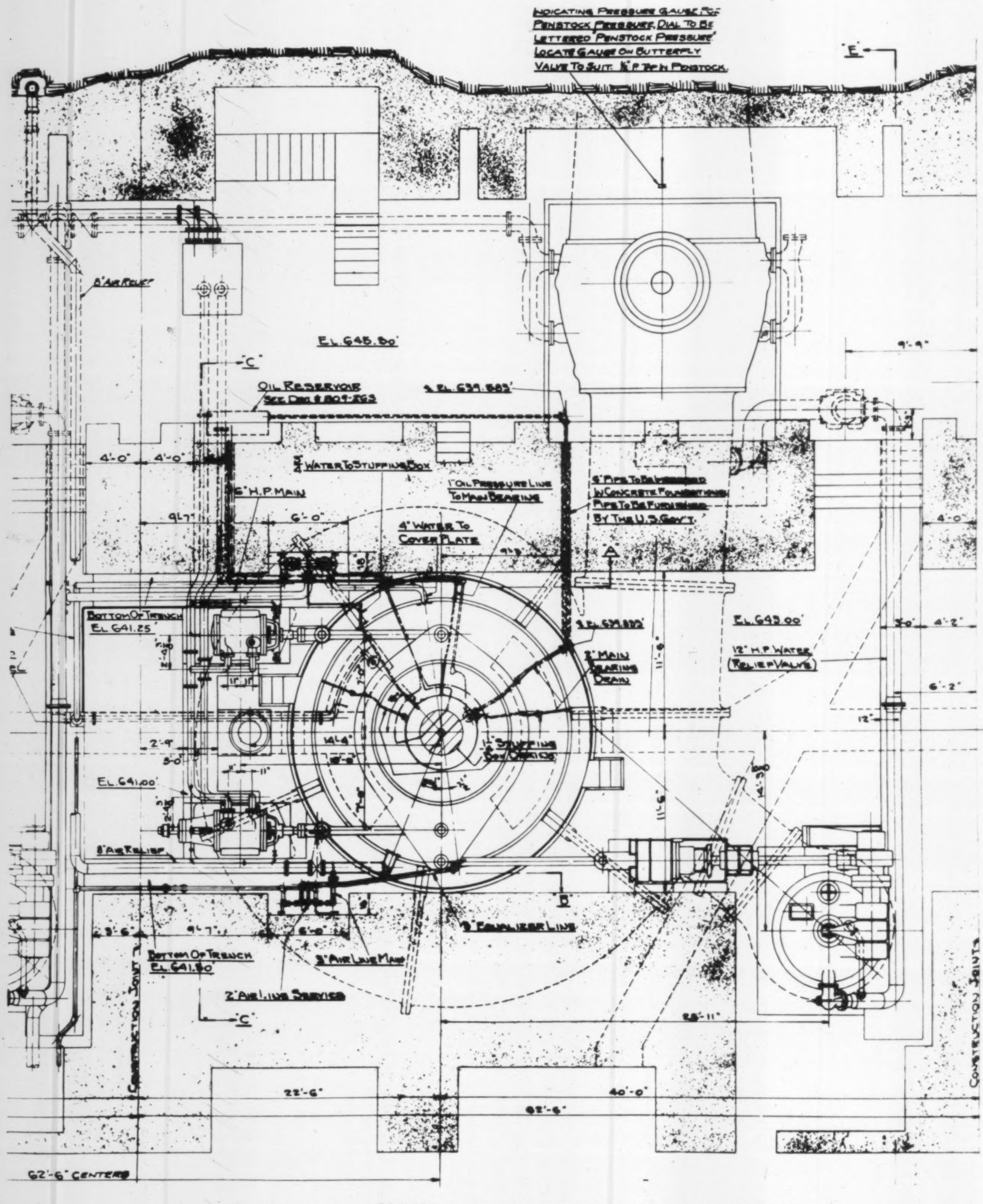

INDICATING PRESSURE GAUGE FOR PENSTOCK PRESSURE, DIAL TO BE LETTERED 'PENSTOCK PRESSURE' LOCATE GAUGE ON BUTTERFLY VALVE TO SUIT. ½" P TAP IN PENSTOCK.
"E"
8" AIR RELIEF
EL. 645.50'
"C"
OIL RESERVOIR SEE DWG # 809-263
℄ EL. 639.883'
9'-9"
4'-0"
4'-0"
¾" WATER TO STUFFING BOX
6" H.P. MAIN
1" OIL PRESSURE LINE TO MAIN BEARING
6" PIPE TO BE IMBEDDED IN CONCRETE FOUNDATIONS. PIPE TO BE FURNISHED BY THE U.S. GOV'T.
9'-7"
6'-0"
4" WATER TO COVER PLATE
4'-0"
"A"
BOTTOM OF TRENCH EL. 641.25'
℄ EL. 639.883'
EL. 643.00'
3'-0"
4'-2"
2" MAIN BEARING DRAIN
12" H.P. WATER (RELIEF VALVE)
6'-2"
12"
2'-9"
5'-0"
14'-4"
1" STUFFING BOX DRAINS
EL. 641.00'
8" AIR RELIEF
"B"
3'-6"
9'-7"
6'-0"
3" EQUALIZER LINE
BOTTOM OF TRENCH EL. 641.50'
3" AIR LINE MAIN
2" AIR LINE SERVICE
"C"
CONSTRUCTION JOINT
28'-11"
CONSTRUCTION JOINTS
22'-6"
40'-0"
62'-6"
62'-6" CENTERS

FIG. 3 PLAN VIEW OF 115,000-HP HYDRAULIC TURBINE AND ITS APPURTENANCES

under which the turbine must operate. The Government specifications provide and the design has been made such that turbine gates cannot close rapidly unless the pressure regulator is proportionately opened.

TESTS TO DETERMINE FLANGE AND WALL THICKNESS

Tests were made to find out what proportion of flange and thickness of wall near the flange to the pipe wall would result in the safest and most economical spiral casing. These tests were conducted on model flanges about one-quarter the size of the flanges of the large casing.

Fig. 4 shows a special interior micrometer designed and applied to determine the separation of the interior edges of the flanges. The scheme consists in the use of a micrometer fixed to the upper pipe wall at the joint and an insulated contact point fixed to the lower pipe wall.

Electrical connections were made to the micrometer and insulated contact point, led to the outside of the casing, and connected to battery and ammeter in such manner that, when contact was made, the ammeter would clearly indicate such contact.

The micrometer was manipulated by a small shaft extending through a stuffing box welded to the pot and terminating in a graduated thumbscrew on the outside. By these means the separation of the flanges could be measured with a degree of accuracy of two ten-thousandths of an inch. All the micrometer measurements were made by experts trained in this method of measuring; the plotted results showing observations made and plotted were probably within two ten-thousandths of an inch of the true value.

The stress in the bolts was not a measure of the force tending to separate the flanges, because as the pipe walls tended to separate, the flanges pinch on the outside adding an additional force tending to stretch the bolts. In order to determine the stress in the bolts, their elongation was measured by micrometer.

Fig. 5 is an illustration of the size of the flanges and bolts and pots used, together with a view of some of the micrometers and extensometers used on the tests.

Fig. 6 shows stress-strain curves for several of the $^3/_8$-in. bolts used on the model test. The material used for the bolts was S.A.E.-3140. The selection of this high-grade and relatively expensive material enabled us to reduce the diameter of the holes in the flanges, and, in fact, the diameter of the flanges as well, which, of course, reduced the bolt circle and thereby reduced the total stresses on the bolting flange. By this arrangement it was found more economical to use this high-quality material than to use the standard material for the bolts.

The plotting on Fig. 6 shows the degree of accuracy with which the micrometer measurements were secured.

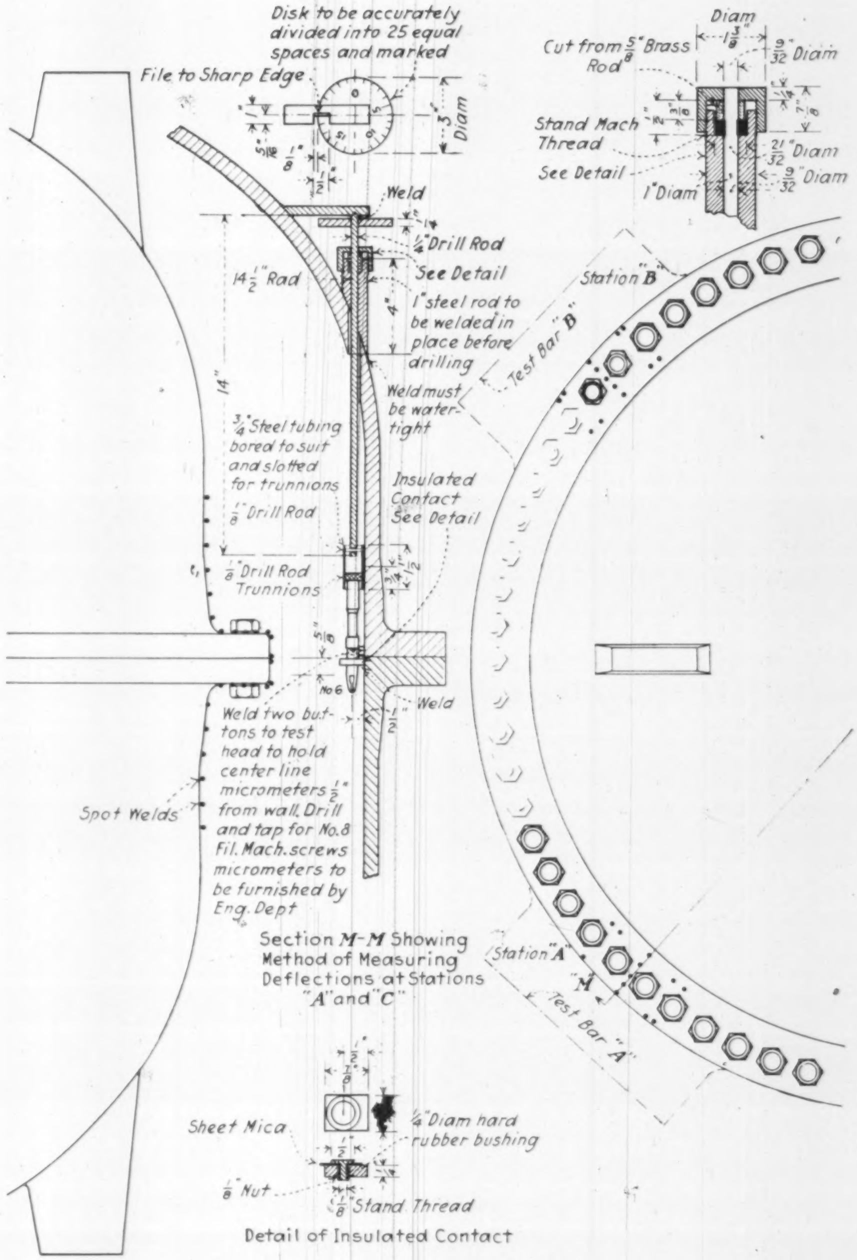

Disk to be accurately divided into 25 equal spaces and marked
File to Sharp Edge
0
5
10
15
3" Diam
1"
5/16"
1/8"
1/2"
Diam
1 3/8"
Cut from 5/8" Brass Rod
9/32" Diam
1/4
3/8
1/2
7/8
Stand Mach Thread
See Detail
21/32" Diam
9/32" Diam
1" Diam
Weld
1/4
1/4" Drill Rod
See Detail
14 1/2" Rad
4"
1" steel rod to be welded in place before drilling
14"
Weld must be water-tight
3/4" Steel tubing bored to suit and slotted for trunnions
1/8" Drill Rod
Insulated Contact See Detail
1/8" Drill Rod Trunnions
3/4
1 1/2"
5/16"
No 6
Weld
1/2"
Weld two buttons to test head to hold center line micrometers 1/2" from wall. Drill and tap for No. 8 Fil. Mach. screws micrometers to be furnished by Eng. Dept
Spot Welds
Station "B"
Test Bar "B"
Station "A"
"M"
Test Bar "A"
Section M-M Showing Method of Measuring Deflections at Stations "A" and "C"
1/2"
7/8"
Sheet Mica
1/4" Diam hard rubber bushing
1/2"
1/8" Nut
1/8" Stand Thread
Detail of Insulated Contact

FIG. 4 DETAIL OF SPECIAL INTERIOR EXTENSOMETER USED IN TESTS ON FLANGE PROPORTIONS AND WALL THICKNESS

Fig. 7 illustrates the results of an attempt to reduce the maximum stress in the flange by pre-extension of the holding bolts.

Chart A of Fig. 7 shows the relation between pressure in the pot and maximum stress in the flange. This maximum stress occurred in the fillet near where the flange joins the pipe.

Chart B of Fig. 7 is the plotting of the relation between the pressure in the pot and stress in the bolts under the three degrees of "preinitial" bolt stress here shown.

Fig. 8 illustrates the relative strength of the flange and tapered billet. A pair of the pots was stretched beyond the elastic limit, then placed in a lathe, and measurements were taken by a lathe indicator. These are plotted to a much enlarged scale. From the plottings it is readily seen that the greatest weakness in this particular flange joint occurs some distance along the pipe from the face of the flange. It should be remembered that the pipe wall near the flange has to withstand the internal test-pressure stress and the stress due to the bending of the flange. This test showed that it was necessary to thicken a portion of the pipe from the flange for a considerable way back into the body of the pipe itself.

It is interesting to note in Fig. 8 that the plotting of the face of the flange and the inside of the flange falls on straight lines with an included angle of 90 deg, showing that the flange itself is not distorted. This means that the dimensions of the flange are ample.

The conclusions reached from the model tests on the various pots with various types of flanges as to diameter, thickness, and various thicknesses of the tapering wall and the body of the pipe, were that 15 lb of metal applied to the cylindrical wall increased the strength 25 per cent, whereas 45 lb applied to increasing the flange diameter increased the strength only 10 per cent. Metal added to the thickness of the wall was, therefore, eight times as effective as metal added to the flange diameter. Tests also showed that adding to the thickness of the flange was even less effective than adding to its diameter.

The data gained from this series of tests made it possible to design flanges and bolting which have been satisfactory for the job.

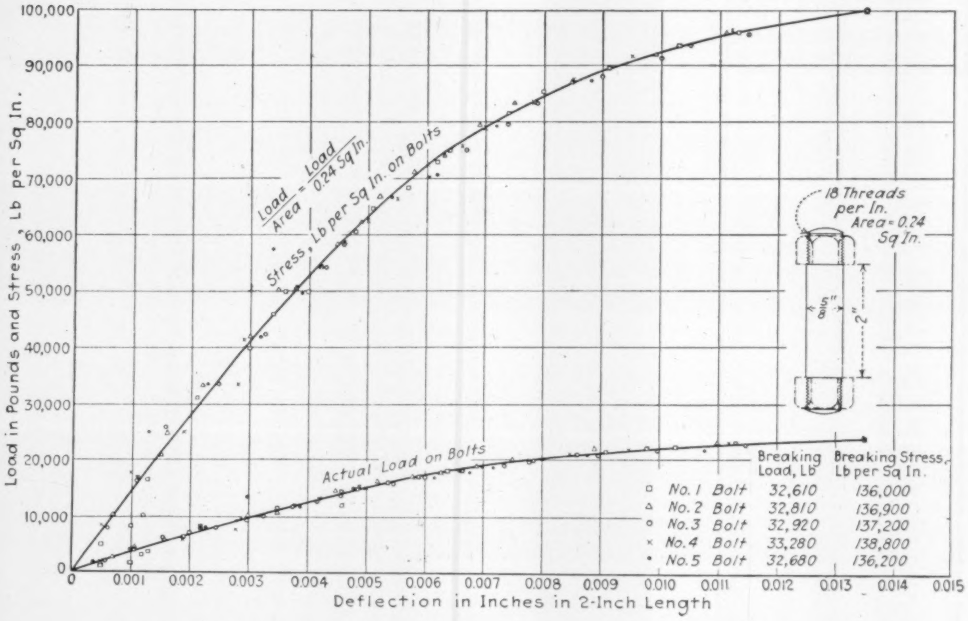


FIG. 6 STRESS-STRAIN CURVES FOR SEVERAL $^5/_8$-IN. BOLTS

TESTS OF SPECIAL CASINGS

Each of the four spiral casings have been tested in the shops of the Allis-Chalmers Manufacturing Company under a pressure of 500 lb per sq in. and have met the requirements of the Government specifications in all particulars.

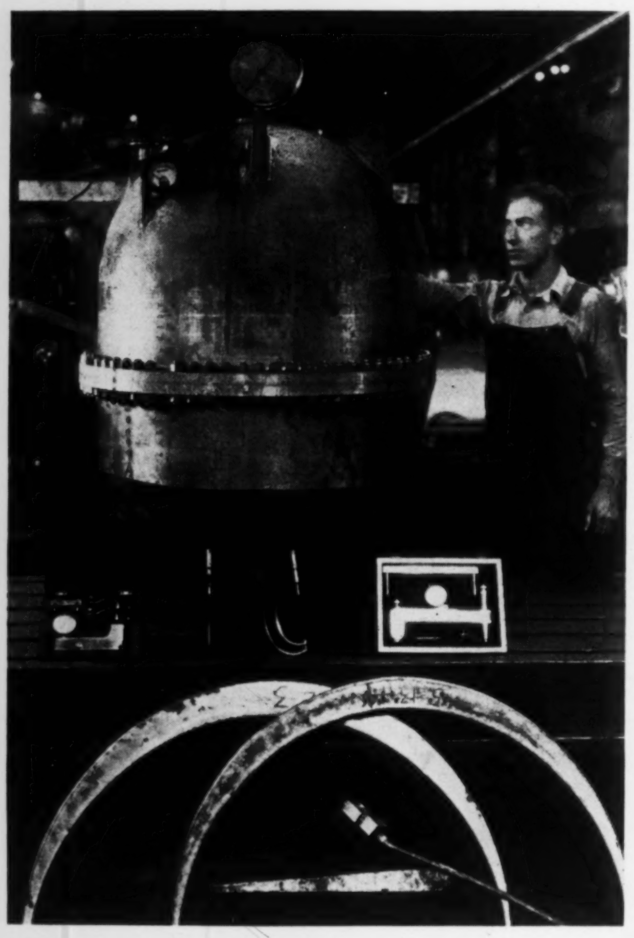


FIG. 5 SPECIAL TEST POT FOR DETERMINING FLANGE PROPORTIONS AND WALL THICKNESS NEAR FLANGE

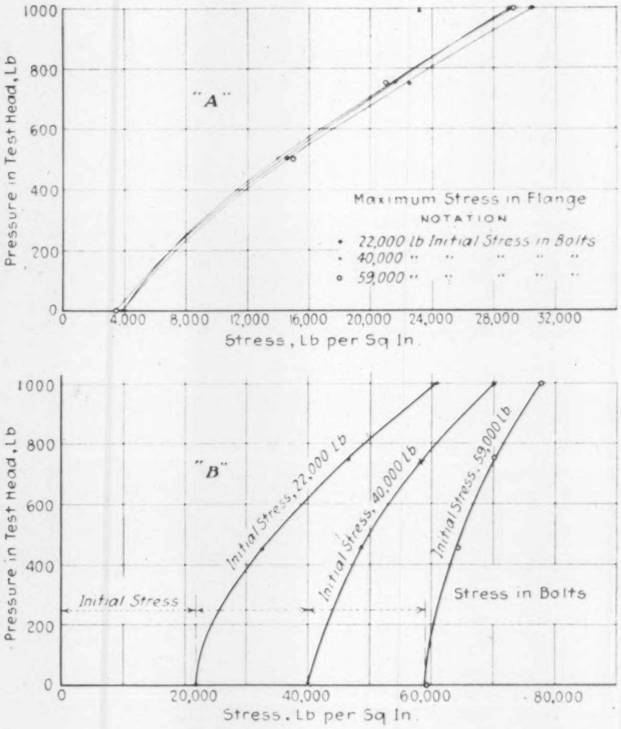


FIG. 7 RESULTS OF ATTEMPTS TO REDUCE MAXIMUM STRESS IN FLANGE BY PRE-EXTENSION OF HOLDING BOLTS

Thirty-six micrometer gages were placed around and about each spiral casing to measure the expansion of the casing walls under the test pressure. When the pressure was relieved, the gage indicators returned to zero, showing no permanent distortion in the castings.

On account of the large size of the casing and the high pressures which will exist in operation, it has been decided by the Government engineers to put a pressure of 250 lb, corresponding to about the maximum normal operating pressure, in the erected

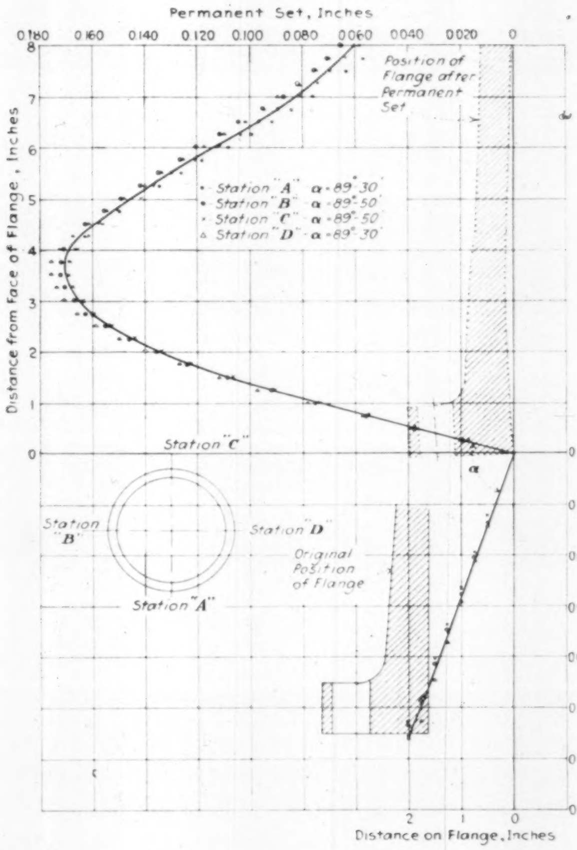


FIG. 8 PERMANENT SET OF FLANGE AFTER STRESSING BEYOND ELASTIC LIMIT

casings and maintain this pressure while the concrete is being poured around the casing and until it has set.

The design of the nozzle outlet from the spiral casing for pressure-regulator discharge was not an easy problem. Fig. 9 shows in the foreground on section No. 2 of the spiral casing the nozzle outlet which has vertical ribs through the opening to support and stiffen the upper and lower walls of that portion of the spiral casing. The two vertical ribs were designed for a thickness of 4 in. each, a width at top and bottom of approximately 40 in., and a width at the center line of the opening of approximately 24 in.

The interior portion of the rib is curved to match in general the contour of the interior of the spiral casing, but the inner edges of the ribs are set about 2 in. inside of the general line of the spiral.

Tests were made on a model of the Boulder Dam turbine embodying spiral casing, speed ring, guide vanes, and draft tube. The model casing was provided with an outlet corresponding to the outlet for the pressure regulator on the main casing. Arrangements were made whereby this outlet opening could be closed. The results of the tests showed that with the pressure-regulator outlet opened, the efficiency was less than with the pressure-regulator outlet closed. This drop in efficiency undoubtedly was due to eddies created by the water flowing past the pressure-regulator opening.

By placing the ribs as shown and setting them slightly toward the inlet of the casing, enough water was skimmed off by pitot-tube action to counteract the formation of the eddy. Model tests showed conclusively that with the ribs installed a better efficiency was obtained than without them.

Another view of the pressure-regulator outlet is illustrated in Fig. 10 which shows the ribbing and how it stiffens the wall of the casing over the outlet. The radial ribs shown are a continuation of the ribs in the nozzle.

The assembled casing shown in Fig. 10 weighs 450,000 lb. The casing was assembled on the erecting floor, lifted by three cranes, and placed over the boring mill shown in Fig. 10. The casing was supported above the mill table and a tool was mounted on the boring-mill table. Thus, the tool rotated while cutting and the casing remained stationary.

Fig. 11 shows the six sections of the first spiral casing loaded for shipment.

The specifications called for a speed of 150 rpm with provisions such that at a later date different runners could be installed and the units operated at 180 rpm. Before casting the 150-rpm runners, work was held up and the City of Los Angeles finally decided to adopt 60 cycles per second for their system instead of 50, which necessitates operating the turbines at 180 rpm instead of 150 as originally contemplated.

A series of model tests was made to determine that form of runner which would give best performance at 180 rpm in the turbine designed for 150 rpm. Satisfactory results were obtained, and it is expected that the power-house performance of the 180-rpm runner will be well above the guarantees made for the 150-rpm runner.

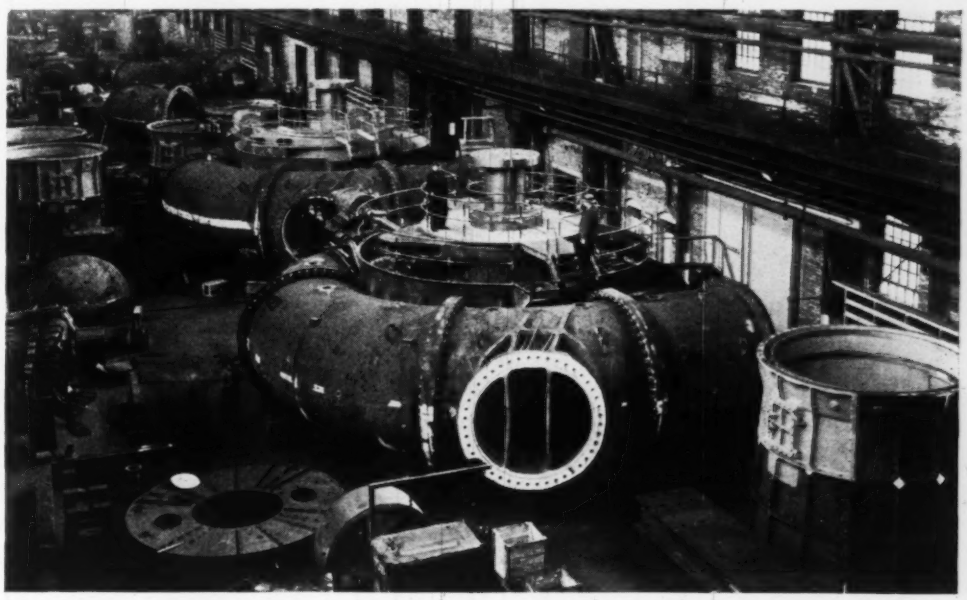


FIG. 9 ONE OF THE 115,000-HP HYDRAULIC TURBINES FOR BOULDER DAM ASSEMBLED IN THE ERECTING SHOP

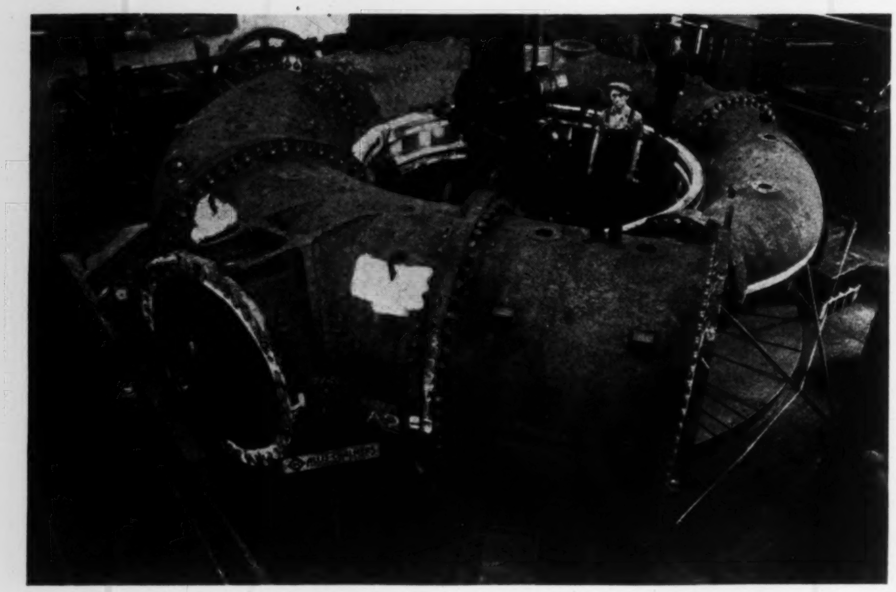


FIG. 10 MACHINING ONE OF THE SPIRAL CASINGS FOR THE 115,000-HP HYDRAULIC TURBINES FOR BOULDER DAM

It is difficult to assign a proper value of plant sigma to the Boulder Dam setting because of the widely varying head and the widely varying tail water. If we arbitrarily select the average operating head of 530 ft and a tail-water level corresponding to the bottom of the runner, it is then easy to compute the value of plant sigma as 0.062. However, if one assumes that the value of plant sigma should be based on the maximum head and the minimum tail-water level, then the value of plant sigma to be here assigned would be 0.037. The value of sigma for the Wheeler plant has been computed to be 0.799, from which it is evident that plant sigma has no meaning except for that particular plant.

ADDITIONAL FACTOR "LAMBDA" PROPOSED

However, the factor of cavitation sigma as related to a given design of turbine runner, once determined at one head, is useful in fixing the elevation of tail water under which that particular design of turbine may be applied when operating under other heads.

The author proposes for adoption an additional factor called λ "lambda" which expresses a relation between turbines of various designs and is based on the fundamental consideration that there must be sufficient absolute pressure in the water in the draft tube at the discharge of the runner to hold the water in contact with the surface of the vanes of the runner. The formula proposed is as follows:

$$\lambda(\text{lambda}) = (H_b - V_b) - Hs - H_t$$

in which H_b is the barometric pressure of the power-plant location minus the vapor pressure; V_b the vapor pressure at water temperature; H_s the distance from bottom edge of the runner vanes to tail-water level (where tail-water level is above the runner vanes, the sign becomes plus instead of minus); and H_t is equal to the velocity head, for maximum guaranteed power, in the draft tube at the discharge of the runner vanes multiplied by the efficiency of the draft tube. In computing the velocity for determining the velocity head, the whirl in the water leaving the runner must be taken into consideration.

Lambda for the Boulder turbines is 15 ft. In other words, the absolute pressure should be sufficient to hold the water in a solid state in the draft tube and should also be sufficient to hold the water along the backs of the vanes of the runner so that there would be a minimum of cavitation.

The formula here proposed does not introduce any new material because this factor is one which has always been taken into consideration in the design and setting of Allis-Chalmers hydraulic turbines. The new factor, however, should afford a convenient reference when considering these important data in the design and setting of hydraulic turbines.

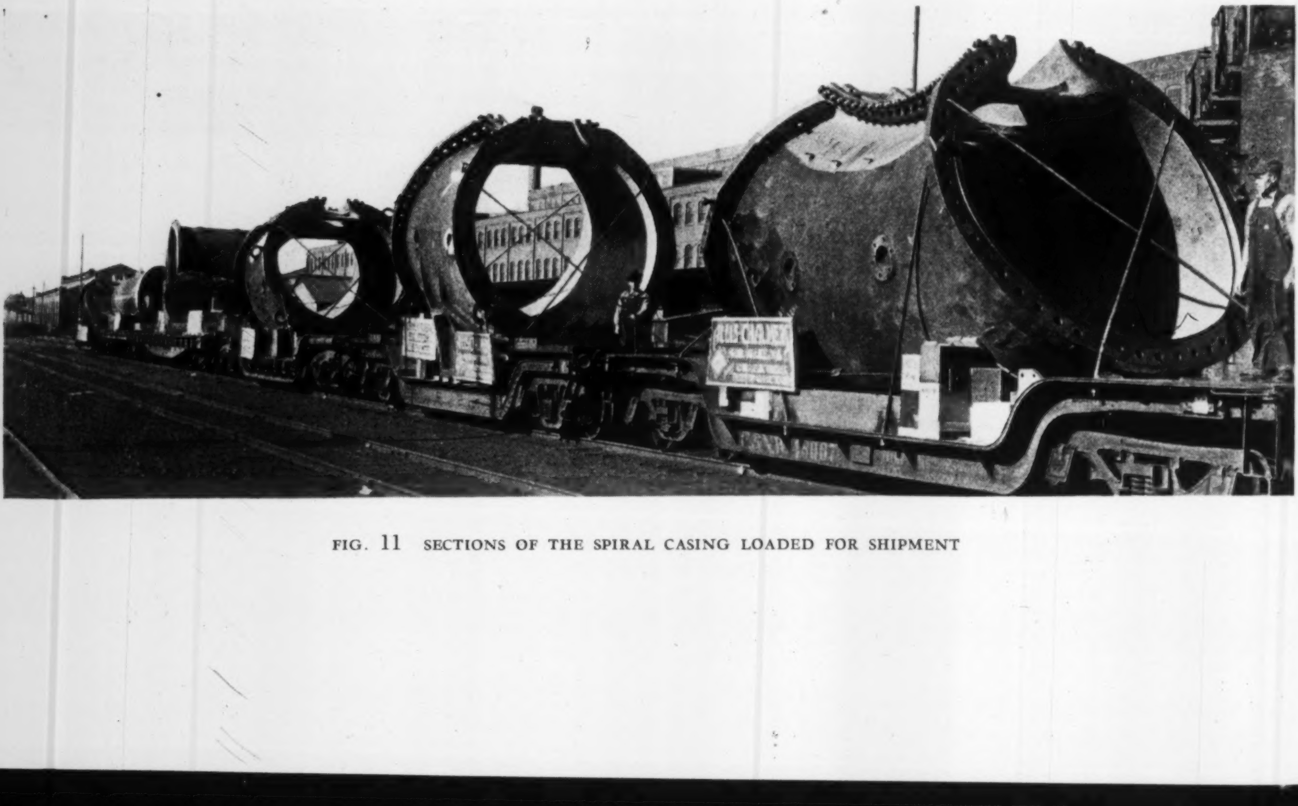


FIG. 11 SECTIONS OF THE SPIRAL CASING LOADED FOR SHIPMENT

The DIESEL ENGINE *for* RAIL TRANSPORTATION

By JOHN DICKSON

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

PUBLIC interest has been aroused by the advent of high-speed, light-weight trains, and the fact that Diesel engines were installed as the motive power of these units has focused attention on the ultimate possibilities of this particular type of engine in the transportation field.

The idea of applying the Diesel engine to rail transportation is not new. Dr. Diesel had visualized this possibility 41 years ago. In his book, "Rational Theory and Construction of a Heat Motor," published in 1894, he said:

"We consider the new motor specially applicable on railways to replace ordinary steam locomotives not only on account of its great economy of fuel but because there is no boiler. In fact the day may possibly come when it may completely change our present system of steam locomotives on existing lines of rails."

If we compare the engine with which Dr. Diesel was working then, using powdered coal as fuel, and the marine and land installations which established the practicability of this type of prime mover, with the comparatively light-weight and high-speed engines being offered today for rail transportation, we may conclude that two avenues of approach have been taken in arriving at the present-day design. The Diesel designer has modified his slow heavy engine to permit higher speed and the gasoline-engine constructor has fortified his light-weight high-speed unit to stand the heavier stresses imposed by the adoption of the Diesel cycle.

FOUR-CYCLE AND TWO-CYCLE ENGINES

In the Diesel engine there are four functions that must be performed to insure combustion of the fuel: (1) The cylinder must be charged with air; (2) this air must be compressed to a temperature to cause ignition of the injected fuel; followed by (3) a period to give adequate combustion during which power is developed; and (4) scavenging or exhausting of the burned gases must take place before the cycle is repeated.

The problem is, Can these operations be adequately performed without detriment to the engine in one up and one down stroke of the piston as in the two-stroke cycle, or is it necessary to be so conservative as to take four strokes of the piston as in the case of the four-cycle engine? The two-cycle engine sacrifices part of its power stroke in exhausting the burned gases, which results in a reduction of the mean effective pressure, say, from 80 brake mep in the four-cycle to 70 brake mep in the two-cycle engine, including the necessary loss of power to drive the blower. Under these conditions the power of the two-cycle engine is greater than that of a four-cycle engine of the same dimensions in the ratio of 140 to 80, an excess of 75 per cent. The advantage of the two-cycle engine, therefore, is that more power can be packed into a smaller space—that for equal power delivered the engine should be lighter in weight, and, presumably, should be less costly to manufacture. Assume a four-cycle engine of 9-in. bore and 12-in. stroke, running at 900 rpm. With a ratio of brake mean effective pressures of 80 to 70, approximately the same stroke-bore ratio, and the same piston speed, a two-cycle engine to deliver the same power would require cylinders with $6^7/_8$-in. bore and a 9-in. stroke, and would operate at 1200 rpm. Admittedly, the two-cycle engine would be smaller and of lighter weight. On the other hand there must be considered the inability of this smaller engine to withstand the same power output as the larger four-cycle engine.

With a power stroke every revolution, the metal surfaces exposed to the combustible gases are subjected to higher mean temperatures. The heat transfer per square inch of surface will be in the ratio of 2 to 1 and will be increased to the approximate ratio of 2.2 to 1 in the engines previously compared because of the greater number of revolutions per minute. A ratio of 2.2 to 1 necessitates careful analysis of heat stresses in the cylinder head, cylinder, and piston, and increases the difficulties of lubricating-oil control.

The total heat transmitted to the cooling water may not differ greatly in the two types because the surfaces exposed to the combustible gases are less in the two-cycle than in the four-cycle engine. Furthermore, the total heat that is transmitted to the cooling water in different designs of two-cycle engines may vary materially and may reflect to a large extent the degree of ingenuity that has been applied in the engine's construction.

The exhaust and scavenging processes of the two-cycle engine have to be completed in approximately 140 crank-angle degrees compared to 450 crank-angle degrees in the four-cycle engine. In the ideal design the need for valve mechanism is eliminated and the head construction is simplified by placing inlet and exhaust ports at the inner end of the cylinder. Unfortunately, this lengthens the path that the burned gases must traverse, forming what is known as "loop scavenging," and many methods have been devised to increase the efficiency of this process. On the downward stroke the piston must uncover the exhaust ports before the scavenge ports, while it would be desirable on the upward stroke to close the exhaust ports before the scavenge ports in order to obtain a slight degree of supercharge. To overcome this it is necessary to incorporate some type of valve in the exhaust or air-charge passages. To be independent of port control by the piston, the cylinder in some designs is constructed with exhaust valves in the head, which gives the advantage of uniflow scavenging. The air charge coming in through ports at the lower end of the cylinder takes the burned gases to the top end and discharges them through the valves. Also, closing and opening of the exhaust valves can be so determined in relation to the air-charge ports as to provide opportunity for supercharging, although care must be exercised in providing adequate area in the valves to prevent throttling, and the valve mechanism must be strong

---

Presented at a meeting of the Philadelphia Section, Philadelphia, Pa., March 26, 1935, of The American Society of Mechanical Engineers.

and yet of light weight in order to minimize the acceleration forces that are set up during the short period the valves must be open.

If comparison is made of the bearing loads in the two types it will be found that with equal cylinder sizes the two-cycle engine's mean load may not exceed that of the four cycle by 10 per cent; however, because the loading is confined to approximately 75 per cent of the bearing surface of the rod in the case of the two-cycle engine compared to 100 per cent in that of the four-cycle engine, the author is of the opinion that it is not advisable to exceed 500 lb per sq in. mean bearing load in the two-cycle design, whereas 650 lb per sq in. would give satisfactory service in the four-cycle engine.

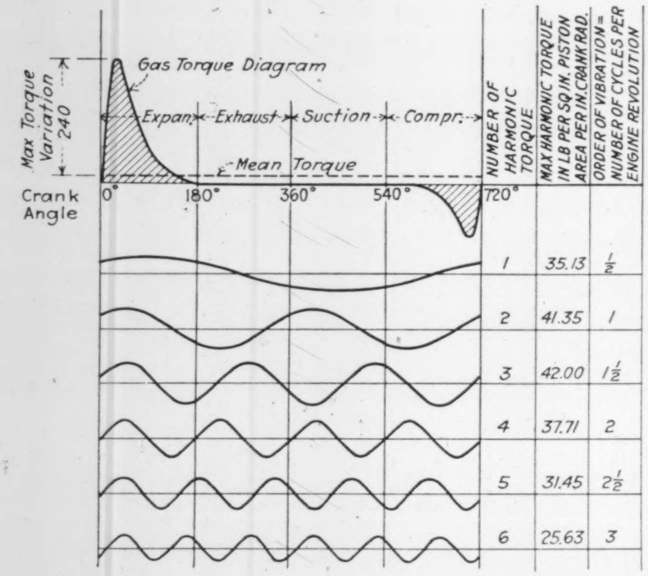


FIG. 1 GAS TORQUE DIAGRAM AND THE FIRST SIX HARMONICS OF WHICH IT IS COMPOSED

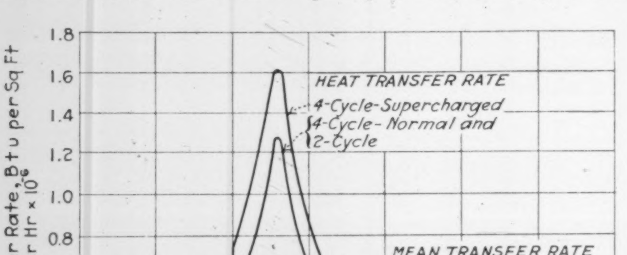


FIG. 2 HEAT-TRANSFER RATES FOR SUPERCHARGED AND NON-SUPERCHARGED ENGINES

In the light of the foregoing comparison of four-cycle and two-cycle engines, the author is of the opinion that the builders of four-cycle engines consider that weight and space requirements can be met to suit any rail-transportation application, especially in view of the prospects of supercharging.

ENGINE SPEEDS

Another problem that is engaging the attention of engine builders today is that of piston speed and engine revolutions. The trend is toward higher speeds with consequent increase in power output. A number of factors must be considered in contemplating raising the engine speed; for instance, Does the fuel consumption per brake horsepower show a tendency to rise rapidly, suggesting lower mechanical efficiency or poorer combustion which may be attributed to throttling? It is necessary to check bearing loads and speeds in order to insure that they come within safe limits. The effects of the revolving and reciprocating masses vary as the square of the speed, which may necessitate the use of aluminum pistons, if not previously employed, and better balance of the revolving masses of connecting rod and crankshaft to reduce main-bearing loads. Control of the lubricating-oil losses is the more difficult, the greater the revolutions per minute. Critical speeds which previously were above the running range may be brought within range and require the application of a torsional-vibration damper.

Westinghouse engines have a 9-in. bore and 12-in. stroke at 900 rpm giving a piston speed of 1800 fpm. At one time it was considered that this was too high a speed and that it would react unfavorably by causing undue maintenance in railroad service. Revenue service has disproved this contention, and engine builders are trying to discover what factors in engine design prevent an increase in rotational speed.

CYLINDER-LINER WEAR

Cylinder-liner wear, which takes place at the top, forming a ridge, appears to be independent of speed. Liner wear expressed in inches of radial wear per thousand hours of operation is found to vary considerably in engines with widely varying speeds with results that cannot be expressed in terms of engine revolutions. Considerable weight must be attached to the contention that condensation of the products of combustion materially influences the wear as reflected by operation with cold cylinder walls, and that differences in fuel oil under stable temperature conditions exert a marked influence. The present trend is to use centrifugally cast nickel-iron liners which have a good homogeneous structure, good rubbing surface, and can be produced at reasonable production cost, although they have been found to be more susceptible to a form of corrosive pitting resulting from "differential aeration" than the carbon-steel liner and the nitrided liner. (The nitrided liner is practically immune to this form of corrosion.) Corrosive pitting occurs on the outside surface of the liner in contact with the cooling water, and results in pit holes which may ultimately destroy the liner. It is influenced by changes in the rate of water flow at localized regions and the amount of dissolved oxygen which the water contains.

PISTONS—LUBRICATING-OIL LOSSES

Reports on several designs indicate that trouble was experienced initially with cracking of aluminum pistons and the excessive wear of the ring lands. The cracking of piston was, no doubt, due to heat treatment of the piston to obtain high Brinell values, and this resulted in large residual stresses which caused ultimate failure in service. Aging the pistons at a lower temperature for a longer period eliminated the residual stresses. The use of permanent molds, both inside and outside, minimizes the tendency toward porosity and reduces the manufacturing costs. Excessive ring-land wear has been traced to cooling, combustion, and fuel oil used and may be corrected without reflection on piston speeds.

So many factors enter into satisfactory control of the lubricating-oil consumption, especially when higher speeds are

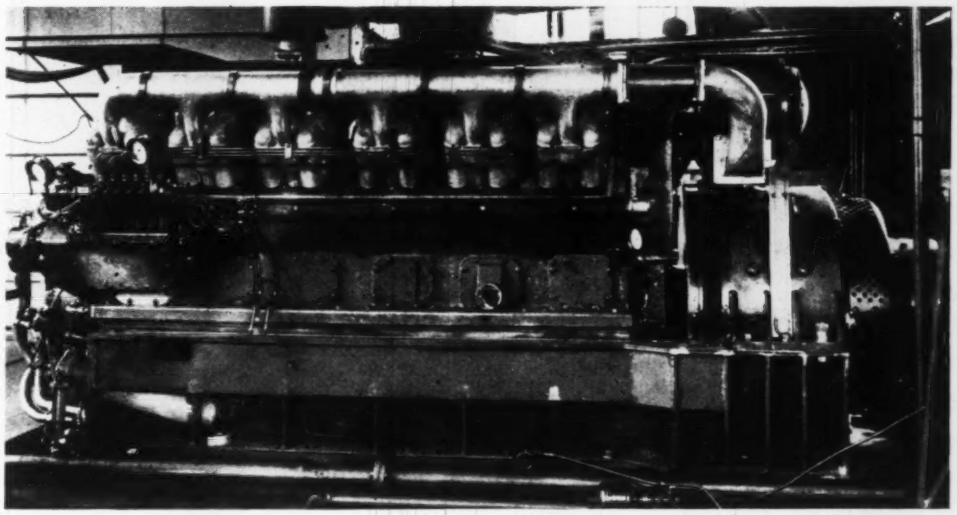


FIG. 4 WESTINGHOUSE 12-V SUPERCHARGED DIESEL ENGINE ON TEST OF BOSTON AND MAINE RAILROAD

(Bore 9 in.; stroke 12 in.; 900 rm.)

entertained, that each design of engine requires its own particular study. The quantity of oil circulated through the bearings depends on the heat to be taken away, which appears to increase as the square of the speed. Part of the oil released from the ends of the connecting-rod bearings is thrown on the cylinder-liner walls, where the amount lost will depend on the piston-ring design and arrangement of oil relief holes in the ring grooves, the length of the piston skirt, and last, but not least, the effect of combustion. In some designs the oil supply to the top of the connecting rod finds its way to the cylinder walls and accounts for additional loss. Baffle plates at the bottom of the cylinder liner to prevent oil thrown from the bearings reaching the liner usually proves ineffective in lowering the consumption. Lubricating oils very much alike in physical characteristic show differences in the amount of oil consumed, although misleading figures are likely to be obtained by neglecting the condition of the remaining oil.

FUEL-PUMP TIMING

Raising the engine speed must be accompanied by an advance in fuel-pump timing to improve combustion. Idling speeds should be maintained as low as possible, especially in switching service where considerable idling takes place and the idling speed is, therefore, quite a factor in the fuel bill. The range of speed between idling and full speed requires variable timing otherwise the maximum bearing loads are increased at the low speeds as a result of the fact that inertia forces are reduced.

Smoothness in running can be greatly improved by attention to balancing the weights of the individual pistons and connecting rods and, no doubt, contributes its share in giving one the impression of the Diesel engine that the higher the speed the "sweeter" it runs.

CRITICAL SPEEDS

The problem of critical speeds is a fundamental one with this type of engine. In switching service the Diesel engine may accelerate and decelerate many times per minute. Each acceleration from idling to full speed may take place in two to three seconds representing an angular acceleration of 20 radians per sec per sec, compared to accelerations of one hundred times this amount which may be experienced in the engine at a critical speed without damping. Crankshafts and auxiliary drives must be designed to withstand this type of loading, resulting in necessity for ample stress factors to withstand the normal accelerations due to changes in the engine speed.

The importance of the problem of torsional vibration may justify giving a few of the elementary factors involved, especially as this type of work is usually assigned to the specialist. The crankshaft, flywheel, and generator armature with the piston and connecting-rod masses concentrated at their crankpin centers have a tendency, when twisted, to vibrate naturally, that is, the crankshaft will twist one way and the generator shaft the other from a point, termed the

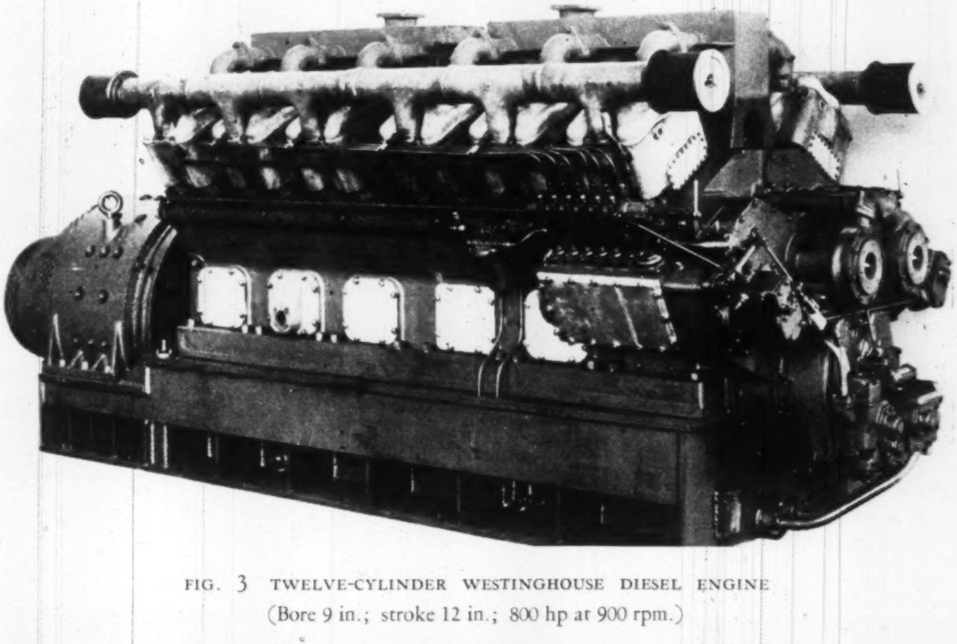


FIG. 3 TWELVE-CYLINDER WESTINGHOUSE DIESEL ENGINE

(Bore 9 in.; stroke 12 in.; 800 hp at 900 rpm.)

node, located between the engine and generator. The frequency of this natural vibration depends on the stiffness of the shaft and the location and magnitude of the masses attached to it. If the gas pressure in each cylinder were a steadily applied force the shaft would simply twist and then revolve in this twisted condition. The forces acting on the crankpin, however, are variable and cyclical. Therefore, the shaft may vibrate naturally with a motion superimposed on the rotary motion.

The gas pressure in the cylinder at each point on the cycle can be found from the indicator card, and from these pressures a torque diagram can be drawn. This torque curve is the resultant of individual forces, and by means of a Fourier analysis of it a true representation of these individual forces that are applied to the crankpin can be determined. The reconstructed torque diagram (see Fig. 1) will consist of a number of individual waves, one repeating itself every two revolutions, another three times, another four times, and so on, so that when the forces of each wave with their positive and negative values are summed up at any point the resultant will be identical with the torque recorded by the torque diagram at that point.

At the crankpin, therefore, there exist a number of regularly repeated forces, any one of which will set up a critical vibration at that rotational speed, if the number of waves it makes per revolution multiplied by the engine speed in revolutions per minute gives a result which coincides with the natural frequency of the shafting. In an engine speed range there may be as many as ten critical speeds, yet only two may be noticeable. Any one of these critical speeds, however, would give rise to vibrations that would break the crankshaft if inherent damping did not exist in the system. When the shaft is stressed there is a hysteresis loss in the metal which the calculator must estimate in determining the amplitude that will be obtained at each critical speed. If the calculated stresses, including concentration factors for oil holes in the shaft, are of such magnitude as to jeopardize the shaft, or if the amplitudes are high at points in the shafting from which gears for the auxiliaries are driven, then external damping in the form of a torsional-vibration damper should be applied.

In regard to the location of auxiliary drives, in engine designs generally these are at the end of the crankshaft where the amplitude is a maximum, whereas the ideal position is between the engine and generator at the nodal point where the amplitudes are negligible. This is where the flywheel is usually placed, its value thus being negligible except as a means of barring the engine over. The torsional-vibration damper should be located at the end of the crankshaft where the amplitude is greatest. The damper consists of two flywheels driven by a spring-borne friction clutch. The spring pressure and coefficient of friction have to be so proportioned relative to the mass of the flywheel rims that when the crankshaft vibrates the flywheels will not vibrate with the shaft, permitting energy to be absorbed in friction between the shaft and the damper rims. Marked differences may exist in the functioning of a damper of this type because of differences in the coefficients of static and running friction in the clutch material used. Scoring of the flywheel rims may weaken its effectiveness if the unit pressures are too high and the material of the rims is not properly chosen. At one time this type of damper was considered of little value due, no doubt, to lack of knowledge of what was required of it. Torsiograph records have proved its initial effectiveness and field service has shown its ability to perform in keeping with other parts of the engine.

The vibration damper has the advantage that it reduces the maximum amplitude and stress but has the disadvantage that it spreads the reduced amplitude over a much wider speed range giving to the crankshaft practically a continuous oscillating motion which can act very unfavorably on auxiliary drives, necessitating in many cases spring flexibility to reduce tooth loading. The four-cylinder "in-line" engine does not present as severe a problem of critical speeds as the 6- or 12-V; and the 8-V is preferable to the "straight eight." It seems desirable to couple the generator and crankshaft rigidly, as this makes possible the definite determination of the critical speeds in advance, a condition that cannot always be met where a flexible coupling is employed.

The four-cylinder engine with the four cranks all in one plane with two cranks 180 deg from the other two has the problem of unbalanced secondary forces which the "straight six," 12-V, and "straight eight" do not have to contend with. In the four-cylinder engine this unbalanced force can be counteracted by applying a dynamic balancer in the form of two

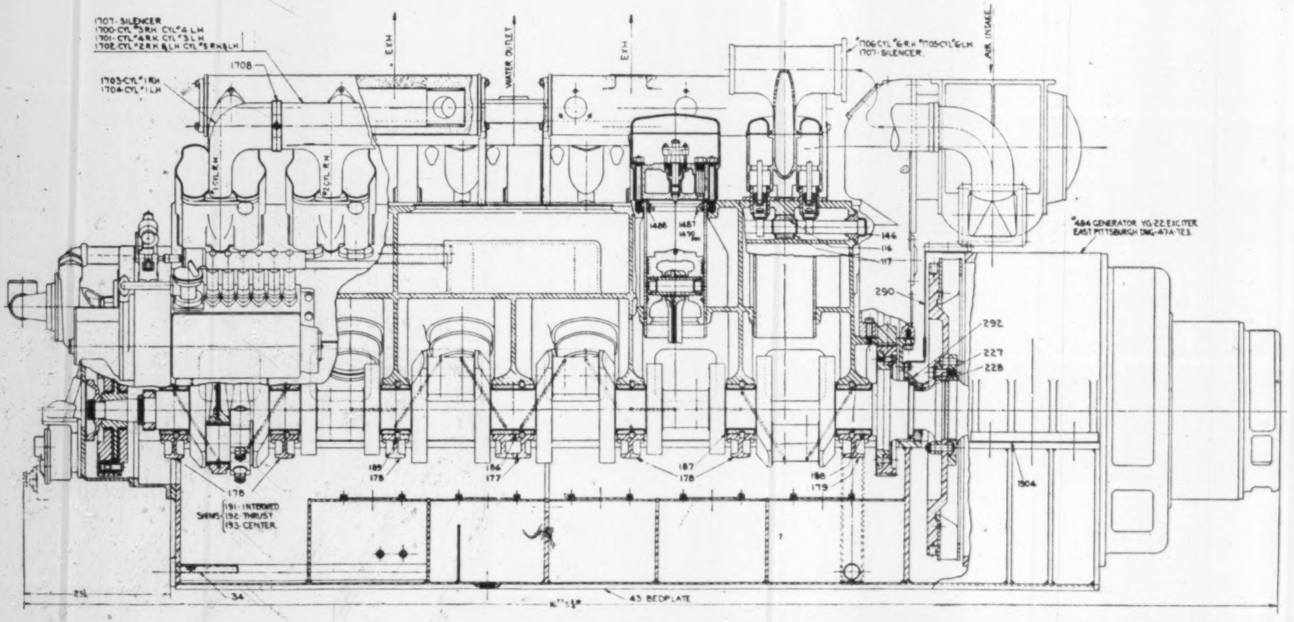


FIG. 5 CROSS-SECTION OF WESTINGHOUSE 12-V SUPERCHARGED DIESEL ENGINE

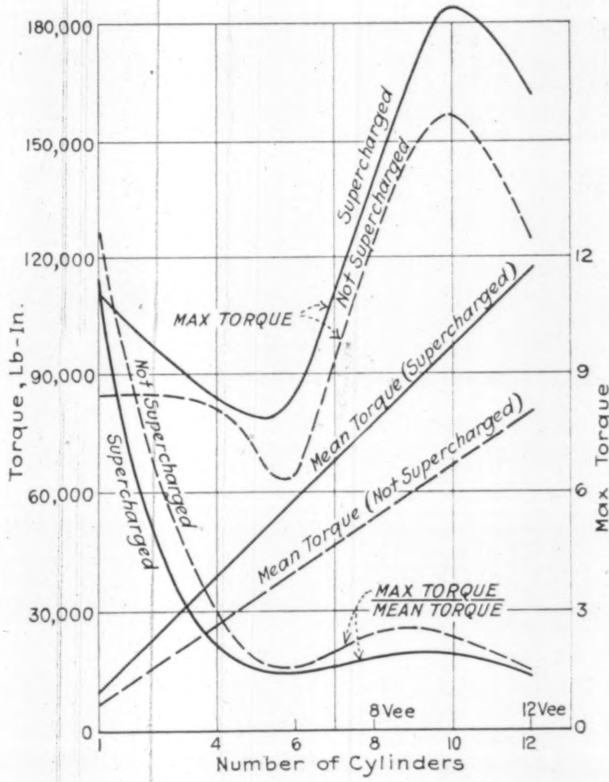


FIG. 6 COMPARISON OF MAXIMUM- AND MEAN-TORQUE RELATIONS OF 9 × 12 ENGINE WITH AND WITHOUT SUPERCHARGING

(900 rpm; mean indicated pressure, 101 not supercharged, 150 supercharged.)

weights driven at twice engine speed, arranged so the weights revolve in opposite directions so that no horizontal forces are set up. Elastic mounting of the four-cylinder engine can be resorted to without a balancer, and this will reduce the load on the engine supports in the ratio of approximately 1 to 30. The disadvantages of elastic mounting are: (1) In starting and stopping the engine the natural frequency of the elastic mounting must be passed through, resulting in extreme rocking of the engine with consequent damage to external piping and connections, and (2) with rubber as the elastic medium deterioration and hardening of the supports takes place, causing the natural frequency to rise into the running range.

CRANKCASE MATERIAL

In the construction of the crankcase which forms the main structure in and around which the other engine parts are assembled, there is a choice of various materials, such as cast steel, nickel cast iron, welded steel, and aluminum. With a cast-steel crankcase the wall thickness must be greater than is necessary from the strength standpoint in order that proper flow of the metal will be obtained in casting. On the other hand, a special technique is required to produce a satisfactory welded-steel crankcase. Such construction usually requires that welded steel be considered for the design from the start in order that such main loads as the cylinder-head studs shall be transmitted directly to the main uprights. Engine noises have not been magnified with the welded construction as was at first expected.

Aluminum has not yet gained ground as a crankcase material, no doubt due to lack of demand for extremely light weight and also to the relatively high cost per pound for a casting of this nature. Nickel cast iron with a tensile strength of 45,000 to 50,000 lb per sq in. appears a good production possibility. The crankcase can be cast to the same wall thickness as the steel casting, machinability is good, and the price per pound is lower. If the crankshaft is fitted to the crankcase, the crankcase should be supported on a substantial base with the crankshaft centerline as close to the holding down bolts as possible. Experience has shown that conservative design that provides rigidity of the crankcase is well worth while.

SUPERCHARGING

By means of supercharging additional power can be obtained. In the standard four-cycle engine atmospheric air is drawn into the cylinder on the downstroke of the piston. A supercharger supplies air under pressure and thus provides a greater weight of air per cycle for combustion. The improvement which has taken place can be credited to more efficient scavenging. Before the completion of the exhaust stroke of a standard engine the inlet valves open, say, 15 deg before top center and the exhaust valves close 30 deg after top center, a period of overlap of 45 deg. This valve setting may have been found from tests to give the best results, nevertheless, a large proportion of the burned gases have not been scavenged from the clearance space because of the back pressure of the exhaust gases leaving the engine. If a blower supplies air to the engine (as in the supercharged engine) with air pressure in excess of the back pressure, then by opening the inlet valves well ahead of top dead-center, say, 85 deg of crank angle, and by delaying the closing of the exhaust valves until approximately 70 deg after top center, this overlap period is increased to 155 deg, which permits thorough scavenging of the clearance

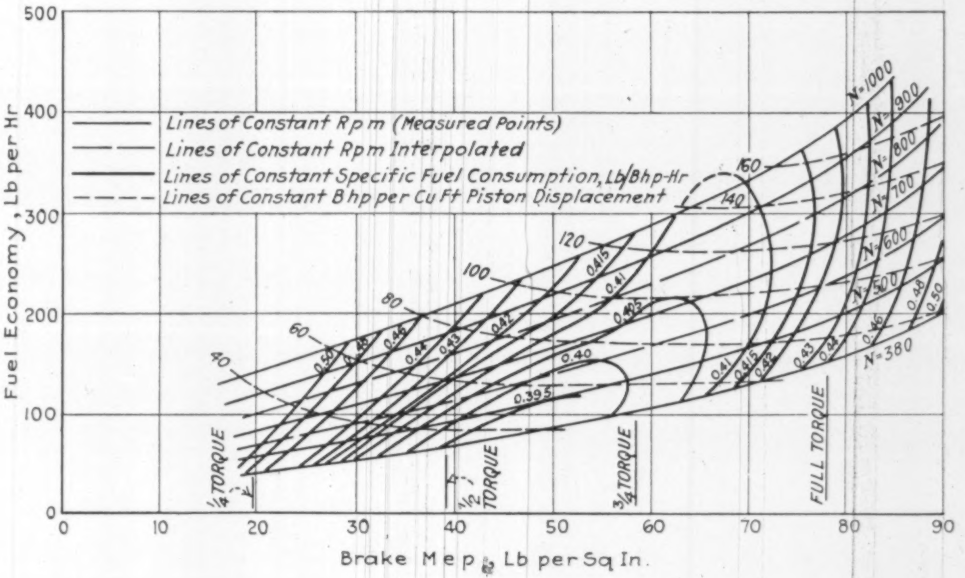


FIG. 7 ENGINE CHARACTERISTICS, 12-V, 9 × 12, WESTINGHOUSE DIESEL ENGINE

space. It is through the adoption of this large valve overlap that new impetus has been given to the development of supercharging for the four-cycle engine. The additional weight of fresh air contained in the clearance space with consequent improvement in the overall combustion has made net power increases of 50 per cent over standard ratings appear feasible compared with previous recognized maximums of 30 per cent. Inasmuch as the power to drive the blower must be added to this it can be realized that good fuel economy is obtained.

What effect, now, has this increase in the power of the engine from a heat and stress standpoint? One of the disadvantages charged against the Diesel engine in the past has been the high pressure encountered during the cycle. The compression pressure of about 400 lb per sq in. followed by a pressure rise to 800 or 900 lb per sq in. upon injection of the fuel gave an indicator card that was narrow at any point between the compression and expansion curves. However, this width can be increased 50 per cent without materially increasing the pressure on the pistons and bearings. Calculated over the two revolutions of the cycle the mean load on the connecting-rod bearings is increased about 4 per cent and that on the center main bearing about 9 per cent—small factors compared with the increase in power. The crankshaft is designed primarily to give satisfactory bearing areas and withstand the conditions met with at critical speeds so that the torque values would not be an influencing factor requiring a shaft of larger diameter. If we consider the temperatures of the gases in the combustion space during the cycle and use Nusselt's equations for rate of heat transfer per square inch of surface we find the mean values compared with the standard engine as 1.36 is to 1, or as 1.36 is to 2 in the two-cycle engine. (See Fig. 2.)

ENGINE PERFORMANCE

The Westinghouse Company has made tests on a single-cylinder engine, a four-cylinder engine, and a 12-V engine under supercharged conditions. Figs. 3, 4, and 5 show the 12-cylinder engine, and Figs. 6, 7, 8, and 9 some of its characteristics. On test when delivering 1320 hp to the generator at 900 rpm the 12-cylinder engine had the same specific fuel consumption as that obtained for the standard engine at 800 hp at 900 rpm, representing an increase in power of 65 per cent. Aluminum pistons were used throughout the tests and did not require protective steel crowns or oil cooling. The temperature of the piston at the top of ring belt was practically the same as under unsupercharged conditions, as determined by fusible plugs. Experimental runs were made to determine the value of steel rings cast in the piston to deflect the heat from the top ring and with a slot cut in the piston above the top ring, but neither method was effective in lowering the temperature at the ring belt.

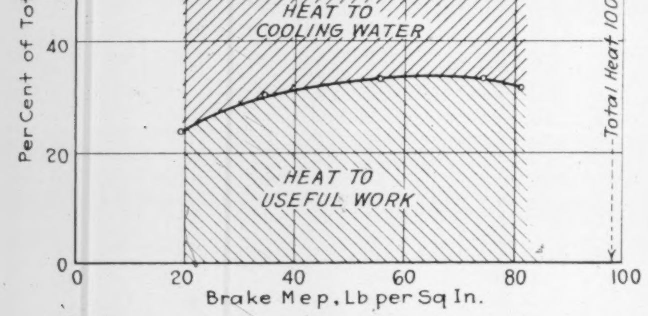


FIG. 8 HEAT BALANCE, 12-V, 9 × 12, WESTINGHOUSE DIESEL ENGINE (900 rpm; variable brake mean effective pressure; lower heating value of fuel 18,500 Btu per lb.)

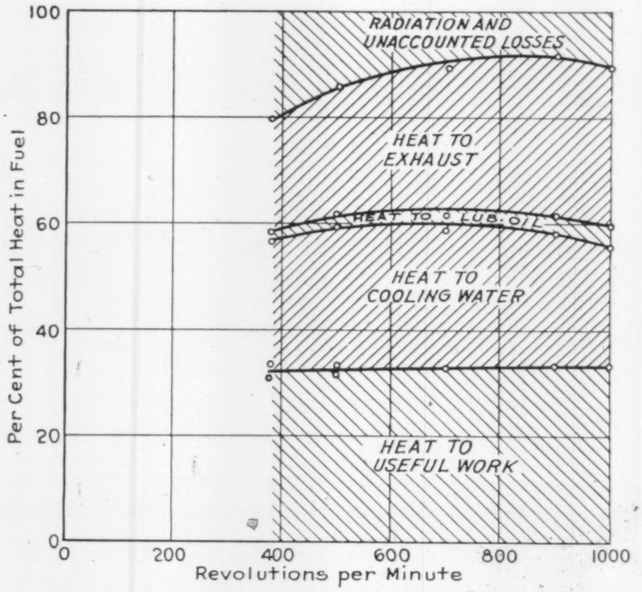


FIG. 9 HEAT BALANCE, 12-V, 9 × 12, WESTINGHOUSE DIESEL ENGINE (Variable speed; brake mep 75 lb per sq in.; lower heating value of fuel 18,500 Btu per lb.)

The total heat delivered to the cooling water with 50 per cent increase in power was found to be the same as that obtained at the 800-hp rating without supercharging. This is a remarkable figure considering that an increase of 36 per cent would be anticipated from the Nusselt equations, and, no doubt, reflects remarkable cooling effects from the period of blow-through of the incoming air. This reduction in heat delivered to the cooling water from what might be expected makes it possible to install smaller radiator capacity than would be necessary for the equivalent power from an unsupercharged engine, and this is quite a factor in rail-transportation equipment.

The heat delivered to the lubricating oil when plotted against the brake mean effective pressure falls along the same curve as plotted for the standard engine, the heat increases approximately as the eighth root of the brake mean effective pressure. For 50 per cent increase this represents approximately 5 per cent, which substantiates the calculated small amount of increase in bearing loads by supercharging.

In concluding it is the author's opinion, based on experience with four-cycle, two-cycle, and four-cycle supercharged engines, that scavenging and air charge are of paramount importance; that the four-cycle supercharged engine permits the best utilization of these factors and provides power outputs comparable with those of the two-cycle engine with the minimum of hardship; and that the future will show an increasing demand for the four-cycle supercharged Diesel engine for rail transportation.

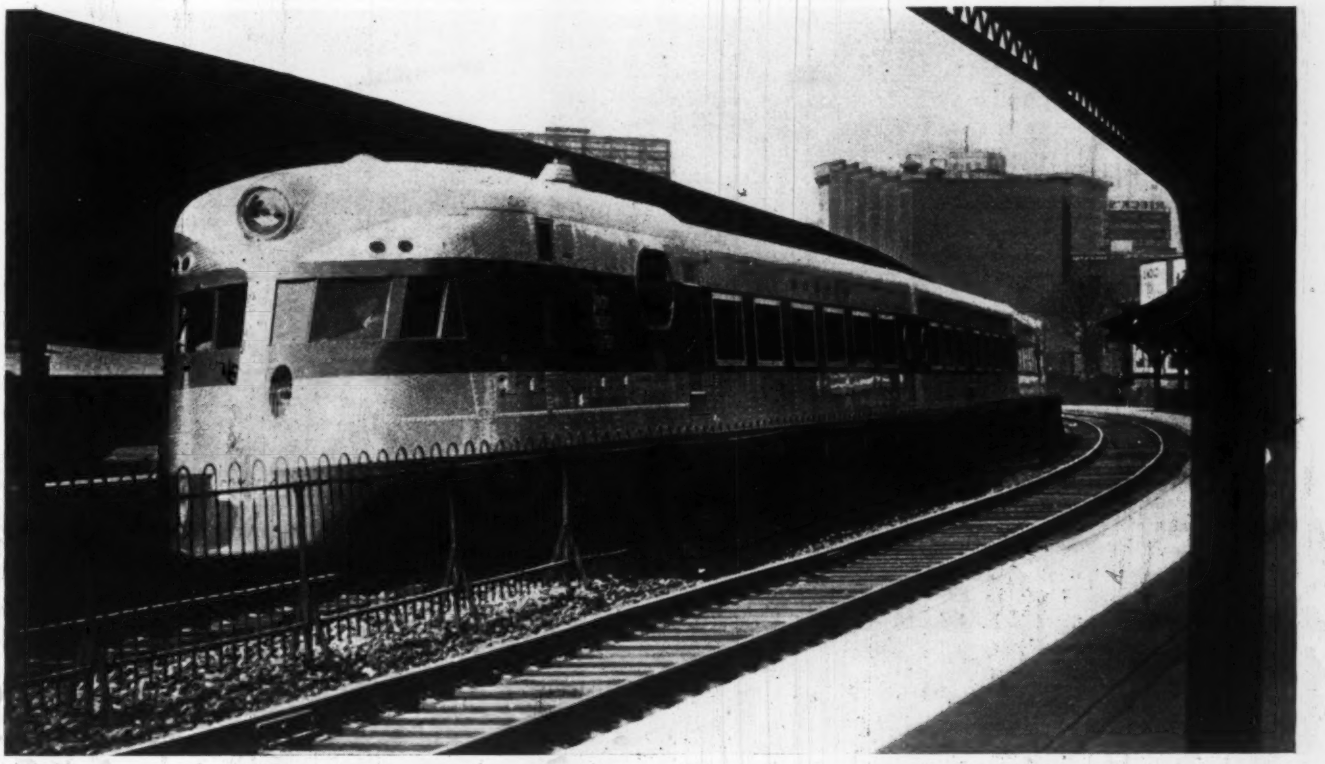


FIG. 15 "THE COMET" FOR THE BOSTON-PROVIDENCE RUN OF THE N.Y., N.H., & H.R.R.

"THE COMET"—HIGH-SPEED TRAIN

Structural, Mechanical, and Aerodynamical Considerations in Its Design

By KARL ARNSTEIN

GOODYEAR-ZEPPELIN CORPORATION, AKRON, OHIO

II—STRUCTURAL DESIGN AND STRENGTH[1]

THE STRUCTURAL design of *The Comet* represents a radical departure from the principles used in conventional railway-car construction in that the entire skin of the roof, side walls, and bottom acts as one of the main load-carrying elements of the structure. This method has been used successfully in modern aircraft design where it is known as the stressed-skin or monocoque type of construction.

The car body resembles a square tube, the four rounded corners of which are reinforced by longitudinal booms of tubular cross-section running the entire length of the car. These four longitudinal members are connected by vertical posts in the side walls, by transverse floor members in the bottom, and by carlines in the roof. The vertical and transverse members make up continuous transverse frames which are also interconnected by a number of lighter longitudinal members in the top, bottom, and side walls. The arrangement of these members and the gages of the outer plates were so chosen that under the most severe loading conditions which might occur in service the plates will not warp or wrinkle and the outside surface of the train will always present a smooth unwrinkled appearance as in Fig. 15. The outer plates are divided by the longitudinal and crosswise members into panels, with or without curvature in the crosswise direction as shown in Fig. 16.

It was necessary to determine the thickness t of the plating required to insure against buckling under various shear loads, longitudinal compressive loads, and combinations of these loads for various values of w, l, and r, Fig. 16. Theoretical solutions are available for the cases of flat panels under compression and under shear[2] and of curved panels under compression.[3] Theoretical solutions have also been found for the related cases of complete cylinders and infinitely long strips under compression and under shear.[4] Most experimental results on panels give only ultimate strengths, which for panels are always greater than the buckling strengths, because lateral edges of the panel resist compression up to the yield point of the material and the panel continues to resist shear as a tension diagonal long after buckling has occurred. Some data on the buckling strength of panels exist, however,[5] and there is considerable information available on cylinders under torsion and under compression[6] and on cylinders under combined loading.[7]

---

[1] Part I, a description of the train and its equipment, appeared in the August issue, pp. 479–482.

[2] "Strength of Materials," by S. Timoshenko. Part 2, D. Van Nostrand, New York, 1930, p. 605; and "The Buckling Load for a Rectangular Plate With Four Clamped Edges," by G. I. Taylor, *Zeitschrift für angewandte Mathematik und Mechanik*, April, 1933.

[3] S. C. Redshaw, Reports and Memoranda No. 1565, Aeronautical Research Committee (London).

[4] "On the Collapse of Tubes by External Pressure," by R. V. Southwell, *Philosophical Magazine*, vol. 25, 1913, p. 687; and "On the Stability Under Shearing Forces of a Flat Elastic Strip," by R. V. Southwell

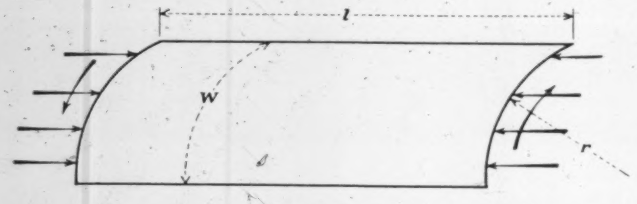


FIG. 16

In general, experimental buckling strengths are below the theoretical (especially in respect to the effect of curvature on the resistance to compression) due to imperfections always present in practice. The curves of Figs. 17, 18, and 19 cover all cases of panels, and were obtained by digesting all the available material in the light of considerable experience with such problems. The curves represent reasonable estimates of the average stresses at which buckling will occur in panels of the smoothness and with the edge support present in the described construction. This edge support is of different stiffness from the hinged edges to which most of the available data apply. The application of these tables requires proper appraisal of actual conditions based on experience. The effect of panel size was therefore estimated from theoretical results on hinged-edge panels, while the effect of curvature was estimated principally from theoretical and experimental results on cylinders. In Fig. 17 is given a formula for the critical compressive stress in terms of the modulus of elasticity of the material E, the thickness of sheet t, the width, length, and radius of curvature of the panel, as defined for Fig. 16, and the factor K_c, which is to be found from the chart. Similarly, Fig. 18 gives a formula for the critical shear stress, the factor K_s being read from the chart. Fig. 19 shows what percentage of each of these critical stresses can be combined before buckling will occur.

Diagonal shear members were used in the side walls only near the articulated ends of the cars where they help to distribute the concentrated truck reactions. Rigid bulkheads are provided not only at the ends of the cars but also near the centers on each side of the vestibules. This arrangement in connection with the stressed-skin construction gives the car body exceptional lateral and torsional stiffness. The four longitudinal booms which are of considerable strength add greatly to the bending and collision strength of the body and offer an ideal protection in case of derailment and overturning.

It can easily be seen why aluminum alloys have been chosen for most of the structure. For a given weight these alloys allow the use of structural elements of greater ruggedness and stiffness than would be possible if high-grade steels were used. This is of particular advantage in a stressed-skin structure, but it was also desirable from a purely practical standpoint that the outside plating of the train should consist of material of a substantial gage. Aluminum-alloy sheet also lends itself readily to the forming of the various curved surfaces needed for good streamline design. For the plating, a new alloy ($52S^1/_2H$) was used which is particularly safe from corrosion and has an endurance higher than other aluminum alloys. For the heavier structural members various simple extruded sections, shaped to fit the requirements of the design, were employed. Another reason for the use of aluminum alloys is the additional safety offered in case of a collision. Theoretical considerations show that aluminum will absorb considerably more energy under the same impact condition than steel by virtue of its lower modulus of elasticity.

The rivets were of aluminum alloy 53SW which has a minimum shear strength of 22,000 lb per sq in. They were squeezed or driven cold by pneumatic tools. Most of the rivets used in the main car structure are $^3/_8$ in. diameter, while $^1/_4$-in. rivets are employed for auxiliary members and $^1/_2$-in. rivets in a few places where exceptional strength was required.

The end sills are of welded cromansil steel construction. They are T-shaped, the top of the "T" extending over the entire width of the car and the leg running approximately 6 ft along the center line of the car. The cross member, at its outer ends, is securely connected to the two lower longitudinal booms. It ties into the end bulkhead and also carries the side bearings. The longitudinal member of the end sill further facilitates the dissipation of the concentrated forces acting upon the end sill.

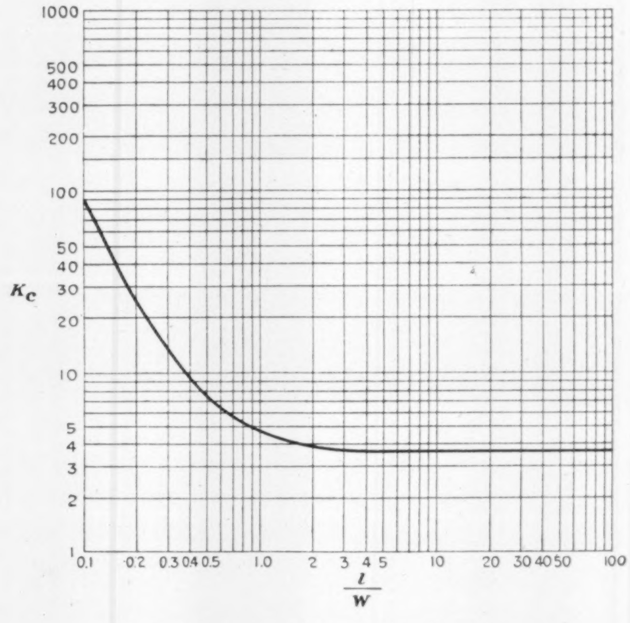


FIG. 17 CRITICAL COMPRESSIVE STRESS

$$E\left[K_c\left(\frac{t}{w}\right)^2 + \left(0.23\,\frac{t}{r} - \frac{1}{20{,}000{,}000}\,\frac{r}{t}\right)\right]$$

$\left(0.23\,\frac{t}{r} - \frac{1}{20{,}000{,}000}\,\frac{r}{t}\right)$ may be neglected if negative.

---

and S. W. Skan, Proceedings, Royal Society of London, vol. 105A, 1924, p. 582.

"A New Theory for the Buckling of Thin Cylinders Under Axial Compression and Bending," by L. H. Donnell, Trans. A.S.M.E., vol. 56, 1934, paper AER-56-12, p. 795.

[5] G. M. Smith, National Advisory Committee for Aeronautics, Tech. Note No. 343.

[6] "Strength Tests of Thin-Walled Duralumin Cylinders in Torsion," by E. E. Lundquist, N.A.C.A. Technical Note No. 427, August, 1932.

"Strength Tests of Thin-Walled Duralumin Cylinders in Compression," by E. E. Lundquist, N.A.C.A. Report No. 473, 1933.

See also paper by L. H. Donnell.[4]

[7] "Some New Experiments on Buckling of Thin-Wall Construction," by F. J. Bridget, C. C. Jerome, and A. B. Vosseller, Trans. A.S.M.E., vol. 56, 1934, paper APM-56-6, p. 569.

"Strength Tests of Thin-Walled Duralumin Cylinders in Combined Transverse Shear and Bending," by E. E. Lundquist, N.A.C.A., Technical Note No. 523, April, 1935.

It is connected with the longitudinal booms by heavy shear plates and at its far end connects through a heavy subfloor cross member to a strong post on either side of the car body. These posts are part of a strong frame and in conjunction with the end bulkhead serve to transmit all vertical reactions and moments into the side panels of the car. The entire design assures great rigidity and a minimum of deformation for the articulated ends of the car.

In the design of *The Comet* the arrangement of a reasonably rigid framing completely bound together by a stressed skin is the novel feature which is probably responsible for the high bending and torsional rigidity experienced in the finished structure.

III—MECHANICS OF THE TRAIN IN MOTION

Even though rail speeds of 100 mph and higher have been experimentally attained in the past with standard passenger-car equipment, the design of the car-body suspension for high-speed, lightweight trains presented new problems to our project engineers.

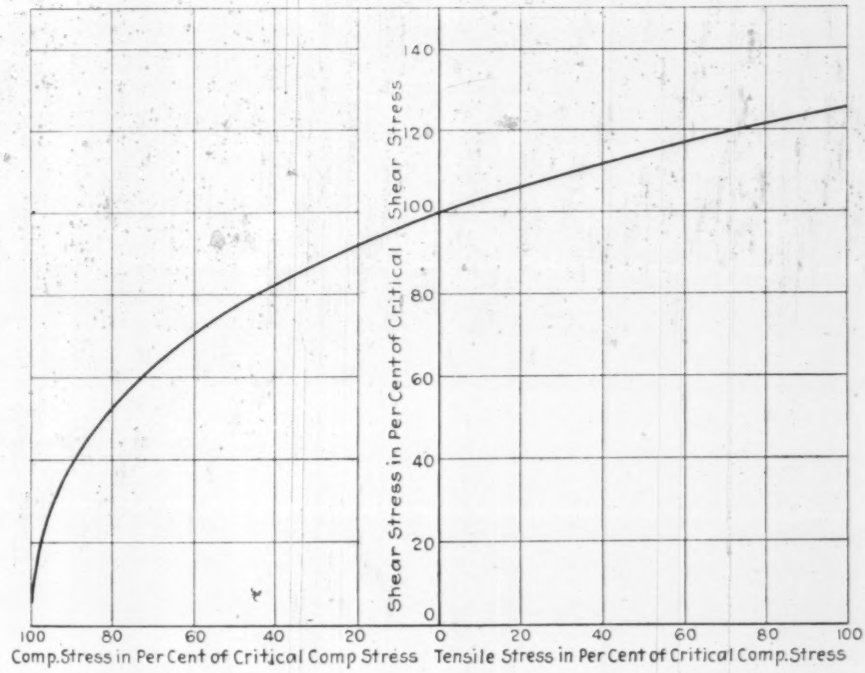


FIG. 19 PERCENTAGES OF CRITICAL STRESSES THAT MAY BE COMBINED BEFORE BUCKLING WILL OCCUR

The reason for developing a special truck design instead of adopting a standard type of truck is found in three salient design characteristics:

(1) Low deadweight causes larger variations of centerplate loading between the light and the loaded conditions. The problems peculiar to low ratios of car body to truck weight may be enhanced for low deadweights.

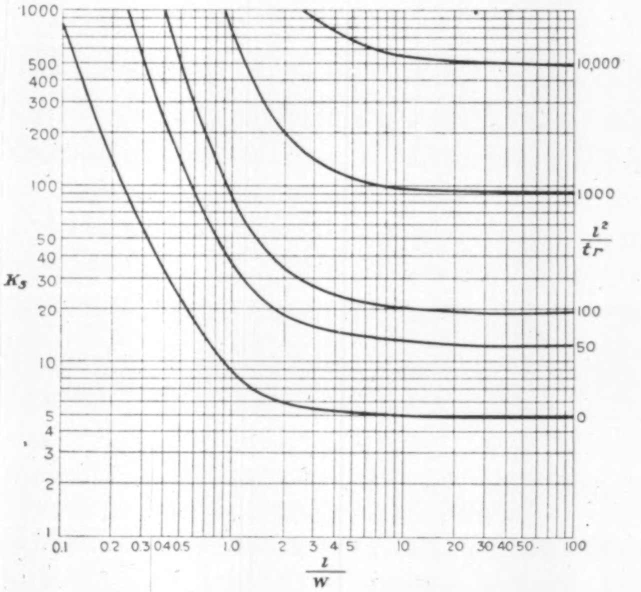


FIG. 18 SHEAR BUCKLING STRESS $= K_s E(t/w)^2$

(2) Low center of gravity.

(3) Higher scheduled speeds, which enhance the requirements for safety and comfort, since track impacts increase with speed.

The design of the car-body and truck suspension divides itself into two main problems; first, the analysis of the mechanical system, and, second, the actual design of the trucks and their connections to the car body.

Even a relatively smooth road bed exerts strong mechanical forces on the trucks of a train moving at high speeds. The spring suspension of the train is expected to minimize the effect of these forces on the car-body proper and to absorb the energies imparted to the unsprung parts. It is impossible to eliminate completely the motion of the car body, since the car has to be mechanically suspended from the trucks, but the type of resulting motion can be controlled in such a manner that it is not annoying to the passengers.

Extensive research in this country and abroad has determined what frequency and type of uniformity of oscillations the human body can easily adjust itself to. Oscillations with a frequency of less than one cycle per second accompanied by a small rate of change of acceleration are not fatiguing even if occasional acceleration peaks to one-tenth *g* are experienced. On the other hand a variety of motions superimposed on each other, such as lateral motion combined with pitching and rolling, are definitely unpleasant, and especially so if there is a rapid change of the type of motion. This happens when one type of motion becomes more pronounced, as would be the case during a transfer of energy from one mode of motion to another.

For greater passenger comfort it appeared desirable to minimize the roll, since it is not necessary for energy absorption. Cars in which the center of gravity is low vary in this respect from conventional cars, where a small angular displacement on the spring suspension makes for a larger amount of travel of the center of gravity. Incidentally, the rolling frequency of a car body increases as the center of gravity is lowered. The roll of a train in which the center of gravity is low would have but little effect on the absorption of lateral rail shocks but would inconvenience the passengers more than on a standard coach.

Since springs have to be soft to minimize the transmission of vertical rail shocks to the car body, it was desirable to utilize a wide spring base on *The Comet* in order to reduce the roll. The hangers carrying the bolster have been sloped three or four times as much as in conventional practice to compensate for the spring deflection. Fig. 22, which is an enlargement of Fig. 11 presented in the first instalment of this paper, shows a power truck.

The kinematic properties of the linkage and springs are such that a centrifugal force displaces the body laterally without rolling it with respect to the truck. Thus the track superelevation is most effectively utilized to bank the car. This not only improves riding comfort but also safety by reducing the difference between inner and outer wheel pressures as compared with conventionally suspended car bodies which lean outward. This advantage is obtained not only under steady centrifugal forces but also in lateral shocks through reactions which naturally depend on the moment of inertia of the car body. Low center of gravity was dictated by the existing track superelevations which, for other practical railroad reasons, have not been increased as much as higher speeds would have suggested.

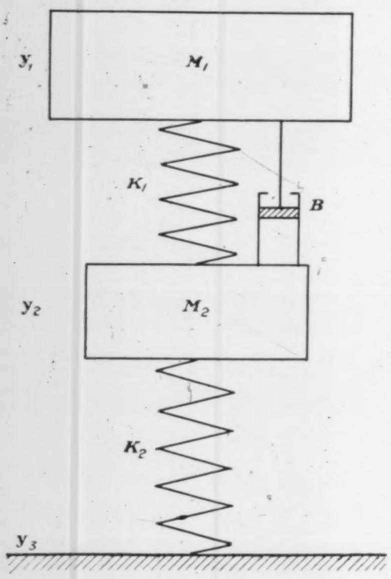


FIG. 20

Mechanically, a three-car articulated train presents a rather complicated system for analysis of the motion caused by disturbances on one of its trucks, if not only the forces on one truck and that part of the car body immediately over it but also the rest of the train are to be considered. Spring coefficients of journal and other springs, geometric relations, moments of inertia, and masses of car bodies and trucks as well as friction and vertical flexibility of side and center bearings and their damping all have their influences. Without attempting a complete analysis of the train suspension, a consideration of the problem of the transmissibility and damping between the truck and car body is perhaps of general interest.

The transmissibility ϵ is defined as the ratio of the disturbance of the car body with the spring suspension to a periodic disturbance applied at the unsprung parts. Generally, the transmissibility has its highest values near the natural frequency of the spring system. If it is very large at this point the operating range should be remote from resonance with the rail-joint frequencies or other periodic disturbances likely to occur. This can be insured, for instance, for the lateral motion of the car body by making the swing hangers sufficiently long so that the natural frequency of this motion becomes low and drops out of the normal operating range leaving a small degree of transmissibility at higher speeds. This condition has been achieved on *The Comet*.

The situation is different where two masses are interconnected by springs as is the case for the truck frame resting on the journal springs in combination with the car body which is again spring-supported from the truck frame. For simplicity, only vertical oscillations will be considered here and the simplified spring diagram, Fig. 20, will be referred to. It can be shown that the same type of reasoning also applies to the combined angular vibrations which incidentally have about the same range of criticals. In Fig. 20 let

M_1 = mass of car body
M_2 = mass of truck
y_1 = motion of car body
y_2 = motion of truck frame
y_3 = motion of wheels and axles
K_1 = bolster-spring coefficient
K_2 = journal-spring coefficient
B = damping constant, which will be assumed to be proportional to $d(y_1 - y_2)/dt$
ω = exciting frequency in cycles per second or train speed in miles per hour
$i = \sqrt{-1}$

The dynamic equilibrium at the two masses can be expressed by the following vector equations:

$$y_1(K_1 - M_1\omega^2 + iB\omega) - y_2\,(K_1 + iB\omega) = 0$$

$$y_2(K_1 + K_2 - M_2\omega^2 + iB\omega) - y_1(K_1 + iB\omega) - y_3K_2 = 0$$

and from these equations the transmissibility results:

$$\epsilon = \sqrt{\frac{(K_1K_2)^2 + (K_2B\omega)^2}{[K_1K_2 - K_1\omega^2(M_1 + M_2) + M_1M_2\omega^4 - K_2M_1\omega^2]^2 + [K_2B\omega - B\omega^3(M_1 + M_2)]^2}}$$

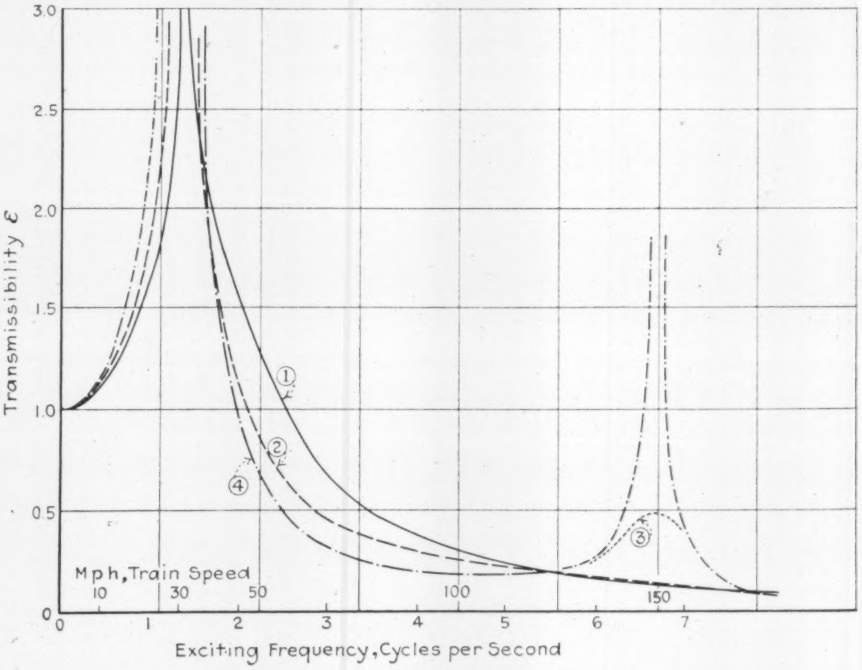


FIG. 21 INFLUENCE OF DAMPING ON TRANSMISSIBILITY OF RAIL-JOINT SHOCKS

(Damping for Curve 1 = 2000 lb per in. per sec; for Curve 2 = 1000 lb per in. per sec; for Curve 3 = 50 lb per in. per sec; for Curve 4 there is no damping.)

Plots of ϵ against ω, Fig. 21, for various amounts of damping show two peaks which coincide with the natural frequencies of the system. The damping helps only in the vicinity of resonances but it increases the transmissibility. Normally, trains operate above the lower maximum of transmissibility which occurs at slow speed and the train passes over it in a relatively short time during acceleration and stopping periods. At this critical speed the actual disturbances are small and no inconvenience to the passengers is experienced.

The second maximum, however, is seldom so low that operation beyond it can be utilized and it was therefore considered better to operate below it. In some cases it has been attempted to operate beyond it and in such cases sufficient damping has to be provided to make the critical range safe for operation. The higher amount of damping required increases the transmissibility beyond resonance and there remains a critical speed in the operating range, so that little if anything is gained by this procedure. This second critical range is largely influenced by the spring constant of the journal springs and the truck mass. A lighter truck moves the critical range higher and reduces the amount of transmissibility. Softer journal springs reduce the transmissibility also but lower the frequency. It is therefore favorable to reduce the truck-frame weight and to soften the journal springs without coming into the critical range or permitting too much roll. This has been done on *The Comet*.

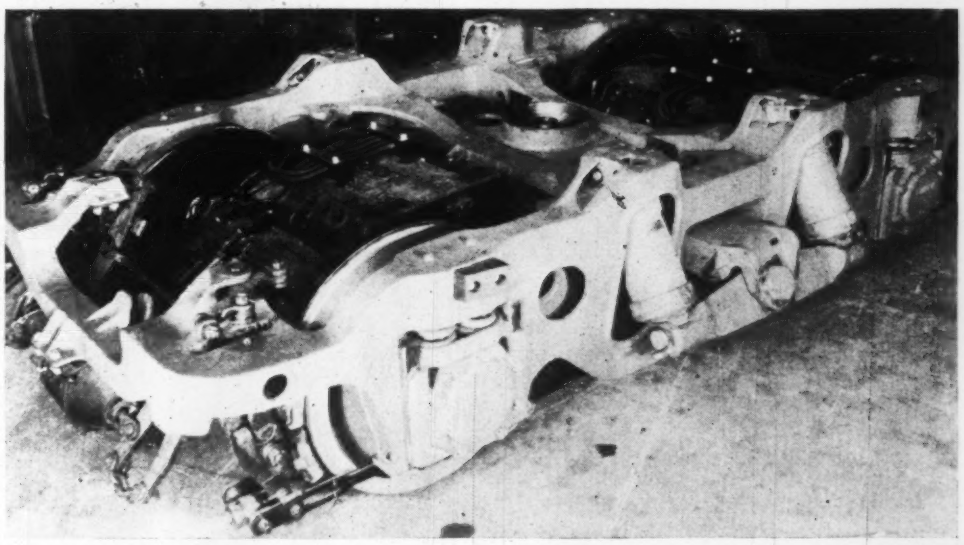


FIG. 22 POWER TRUCK, SHOWING SHOCK ABSORBERS

Damping, although generally detrimental to transmissibility, is necessary for operation near the critical-speed range and for steadying the car body after such disturbances as caused by cross-overs and track irregularities. Normally, friction between moving parts consumes some energy and gradually reduces the amplitudes of ensuing oscillations.

Since it is impossible to eliminate friction entirely in actual suspensions embodying hydraulic shock absorbers, the damping forces vary proportionally to less than the square of the oscillatory velocities. In the case of *The Comet*, friction has been kept quite low through the use of special bushing and bearing materials.

Damping devices can be designed to offer resistance increasing directly proportional to the speed and to the square of the speed, as in hydraulic damping where a liquid is pressed through an orifice. The "square speed" damping has relatively small effect on the transmissibility and it is therefore a good means of damping.

The hydraulic shock absorbers supplied on *The Comet* were adjusted to furnish a strong damping force on the rebound but very little damping opposing the first action of the springs. This rather simple device is quite effective.

Little design difficulty was experienced in providing two pairs of concentric flexible coil springs over each journal box and to provide generous rubber pads on top and below the coil springs. While the truck loses part of its flexibility due to the elimination of the equalizer, actual experience showed that the flexibility was still sufficient, especially since other equalizing means were provided in the bolster suspension. The unsprung weight was thus kept small due to the absence of unsprung equalizers, and, what is still more important, the frequency of the "nosing" of the truck became so high that resonance with the rail-joint frequency was impossible in the operating range.

The trucks were designed to have a long wheelbase in order to prevent hunting. The wheelbase of the power trucks is 8 ft 3 in. and that of the articulated trucks 8 ft 8 in. Figs. 10 and 11 of the first part of this paper, page 481 of the August issue, show the trucks. Fig. 11 is reproduced here as Fig. 22.

The actual design of the trucks embodies all these considerations and laboratory and road tests were made to confirm them. The four-wheel trucks of *The Comet* have one-piece cast-nickel steel frames of box-type design. The frames are extremely rigid and of moderate weight. On account of their importance in the whole train, they were not only carefully stress-analyzed so that the metal could be placed to best advantage, but they were also tested with 100 per cent overload and deflections and stresses were measured at strategic points. Pedestals are integral with the truck frame and two double-coiled springs are placed on top of each journal box with a steel-rubber-steel sandwich on top and bottom. Roller bearings are used. The axle assemblies were dynamically balanced before installation.

The cast-steel bolsters are supported on both ends by equalizers which in turn are hung from the truck frame by two shock absorbers on each side. These shock absorbers replace the swing hangers and elliptic springs of the conventional truck. They are hollow cylinders in which flexible coil springs have been installed under initial compression. These springs rest on a piston which is connected by a piston rod to the upper end. Under normal load the piston floats at about the center of the available travel. The units are filled with oil which is pressed through measuring orifices in the piston whenever the piston travels under a variation of load. The shock absorbers are installed at an angle to the vertical, and the slope compensates for the deflection of the springs and prevents rolling. The spring base at the lower ends of the shock absorbers is unusually wide. It utilizes almost the full width of the train. The bolsters are guided between the two center transoms by spring-steel wear plates, and rubber cushions are provided on the articulated

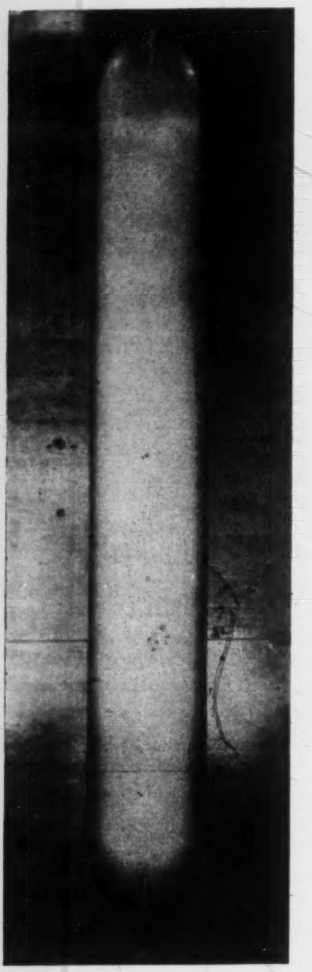


FIG. 23 WIND-TUNNEL MODEL, SHOWING FRONT AND REAR ENDS IDENTICAL FOR DOUBLE-END OPERATION

trucks. The center bearings are integral with the bolster and completely rubber insulated. They are very low, thereby reducing the amount of weight transfer from one axle to the other during braking and accelerating periods.

Clasp brakes with two cylinders per truck are installed on both types of trucks and the specific brake-shoe pressure has been kept low on the power trucks by using four shoes per wheel. Another interesting feature of the truck design is that it permits a low floor height ($32^1/_2$ in. above the top of the rail) and that the lower side girder of the car-body structure can pass alongside of them, thus placing the trucks really inside the car body and eliminating the necessity of special cowlings to reduce air resistance. To provide a certain degree of flexibility between car bodies, shear rubber springs are used on the side bearings of the articulated trucks.

The trucks have been tried out in service during the test trials, the delivery trip to New Haven, and on the New Haven Railroad over various types of track. The results have been very satisfactory and in close agreement with the expected performance. Critical speeds, hunting, or other undesirable features have not developed at speeds up to 110 mph without necessity for a single adjustment.

IV—AERODYNAMICAL CONSIDERATIONS

Before undertaking the design of fast trains an extensive study of the air forces acting on trains was started in order to learn more about their possible importance and the conditions under which radical streamlining would become of paramount importance. In the course of this study many new wind-tunnel model tests were conducted, some of them of an unusual nature. These tests were devised to give answers on certain specific questions rather than to measure a conventional drag coefficient on a true-scale model and to try to apply it directly to a full-size train.

The air resistance of a train may be considered to result from several separate influences whose relative importance may be quite different in a wind-tunnel model test and on a full-size train unless some special artifice is used. These various influences are: (1) The shape of the head and tail, which affects the form drag; (2) the length and exposed circumference (and the shape, if poor) of the body, which controls the smooth-skin-friction drag; (3) the roughness of the skin where exposed to free air flow, which influences the laws governing skin-friction drag (this roughness is exemplified by rivet heads, window and door recesses, and similar surface irregularities); (4) the drag of projecting parts such as buffers, handles, and headlights; (5) the air friction between the bottom of the cars and the ground and the resistance of the trucks; (6) the impulse drag of radiator air intake and engine air intake and gas exhaust, and the influence of these disturbances of the outer air flow upon the form and friction drag; and (7) atmospheric influences such as air density and winds. These influences are discussed separately in the following paragraphs.

The head and tail end of *The Comet* were to be symmetrical for double-end operation. This meant an aerodynamical compromise, inasmuch as a head end having the slender shape of the best imaginable tail would have added more length and complications in visibility than were deemed worth while in view of the other drag components. The influence of the tail shape fades with increasing train length. *The Comet* is a train of moderate length in this respect. However, an easily rounded head with a well-faired headlight was striven for. Model drag experiments were made in the 6.5-ft 120-mph wind tunnel of the Daniel Guggenheim Airship Institute in Akron[8] which is under the direction of T. Troller. The shape of one of the models can be seen in Fig. 23. The models were built to a scale of 1 to 12.

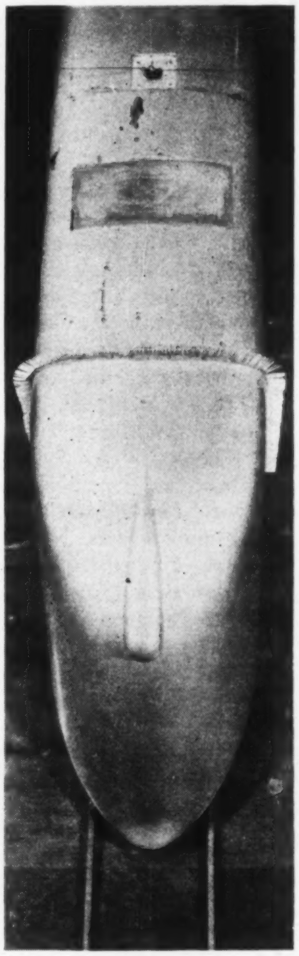


FIG. 24 WIND-TUNNEL MODEL EQUIPPED WITH A COLLAR OF TAPERED QUILLS TO INSURE TURBULENCE AND AN ARTIFICIAL INCREASE OF BOUNDARY-LAYER THICKNESS DOWNSTREAM

It was suspected that the efficiency of a tail shape in keeping the wake small might depend upon the relative thickness of the friction boundary layer accumulated at the rear end of the cylindrical part of the train. For the purpose of studying this influence, a curious experiment was tried at the suggestion of our research department. The model was equipped with a collar or comb of tapered quills, visible in Fig. 24. These not only insured turbulence of the boundary-layer flow but also gave rise to an artificial increase of the boundary-layer thickness downstream. It was hoped that this would have an effect upon the flow about the tail end similar to that of a much longer train. Thus, although a definite proof for this theory was not yet obtained, the feasibility of the method was established.

These and most other tests were made with a large ground board to duplicate at least in part the influence of the ground surface upon the streamlines. In order to obtain a clue to the possible influence of the boundary layer which builds up on the ground board itself, several velocity-head traverses

---

[8] The Daniel Guggenheim Airship Institute Publication No. 1, 1933.

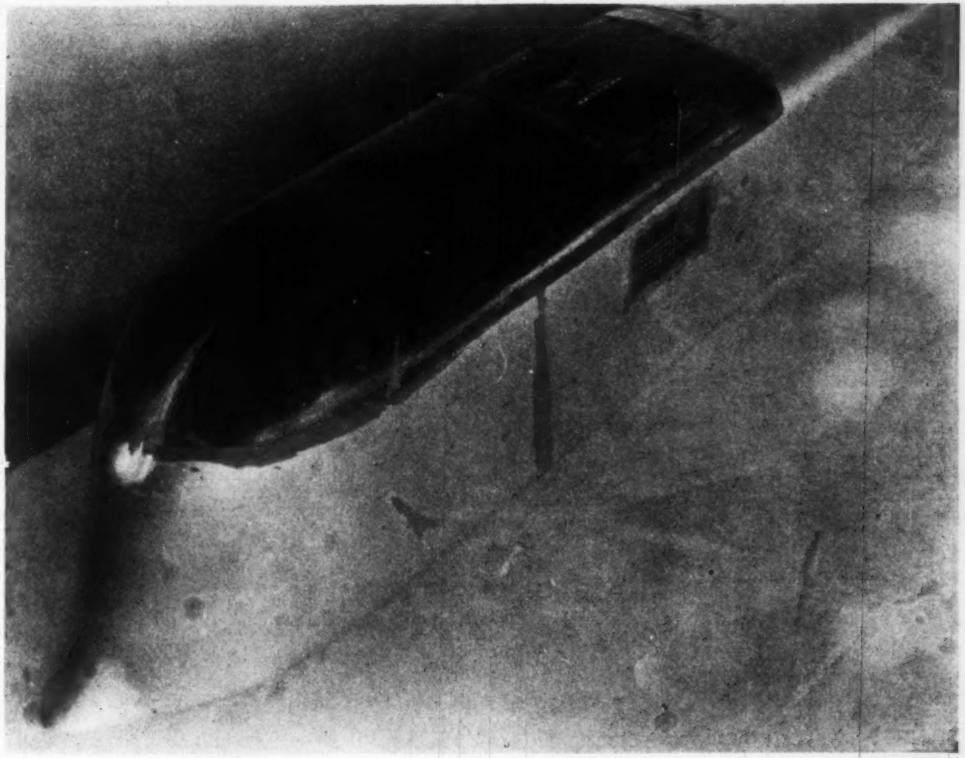


FIG. 26 WIND-TUNNEL MODEL, SHOWING RADIATOR COOLING-AIR INTAKE AND DISCHARGE OPENINGS

were measured on it in the absence of the train model. This ground board extended beyond the jet boundaries and close to the tunnel nozzle and had a well-faired symmetrical leading edge. Detachment at the leading edge and variation of static pressure were prevented by guide vanes. These tests showed that the boundary layers between the board and the bottom of the model did not grow together even for the longest models tested. Although streamer exploration did reveal some flow divergence underneath the car bottom, the drag error due to skin friction on the board was probably small for such a model which had a fairly smooth bottom devoid of sharp corners and edges.

Skin friction is undoubtedly responsible for a good part of the entire air resistance of a train. No attempt was made to determine skin friction on models of trains or to extrapolate from them to full size. In a model of good streamline shape an appreciable part of the boundary layer might have laminar texture, while in full size turbulence undoubtedly predominates. The laws governing friction drag would therefore be different to a degree not known without tedious experimentation. Instead, the theoretical skin-friction drag of the train was computed according to von Kármán's[9] theory. Fig. 25 gives the results of this calculation for a range of speeds and surface lengths of immediate interest for rail trains. The drag per foot of breadth or exposed circumference increases at a slightly smaller rate than the length and the velocity head. The variation cannot be expressed by a fractional-exponent law over any large range of speed and length, but requires an expression containing a logarithmic term. For short-range interpolation between lengths of 200 and 400 ft, and between speeds of 70 and 120 mph, the specific drag (per unit breadth) appears approximately proportional to a length about 50 ft greater than the train length and to the square of a speed about 7 mph higher than the train speed. There is some uncertainty, of course, as to the equivalent length to be attributed to the head and tail where the surfaces are doubly curved.

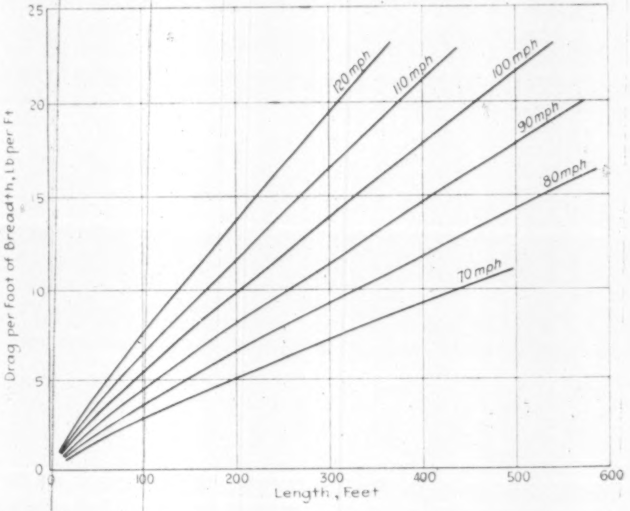


FIG. 25 DRAG OF SMOOTH FLAT PLATE

Every effort was made on *The Comet* to approach an aerodynamically smooth skin surface. Window and door recesses were kept very small and beveled, the articulated ends of the cars were covered with a smooth rubber diaphragm and interruptions of the smoothness of the contour were avoided or minimized wherever feasible. Even so, such recesses as remained and the rivet heads and beveled-plate butts can be considered as a certain scattered roughness. The theory of friction of a rough plate, reviewed also by von Kármán (loc. cit.), indicates that for a train speed around 100 mph roughnesses measured in terms of a "mean height" parameter of less than about 0.001 in. in the forward part and of 0.002 in. in the rear part of a long train would still be aerodynamically smooth. The coarser and denser the roughness, the more the local skin friction increases. Longitudinal rivet rows have some remote resemblance to the artificially roughened surfaces for which accurate experimental data are available. For such surfaces the local friction-drag coefficient (as conventionally defined) per unit of surface area and velocity head approaches a limit at a distance several thousand times the mean roughness height from the leading edges. On *The Comet* probably only a small percentage of the entire windswept surface is roughened to such a degree.

---

[9] "Turbulence and Skin Friction," by Th. von Kármán, *Journal of the Aeronautical Sciences*, January, 1934.

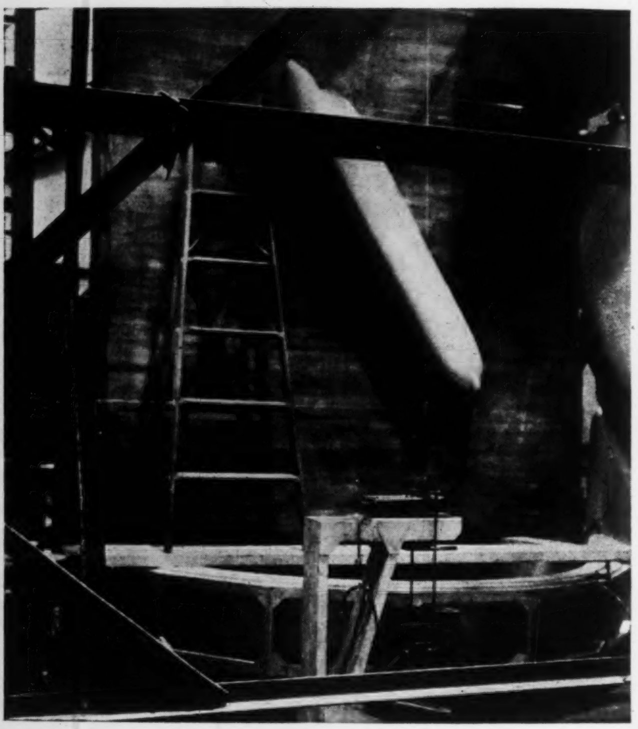


FIG. 27 WIND-TUNNEL MODEL SET UP TO MEASURE LATERAL AIR FORCE, ROLLING MOMENT, AND YAWING MOMENT DUE TO SIDE WIND COMBINED WITH FORWARD SPEED

Individual projections extending through the boundary layer into free air are comparatively easy to deal with. They can be tested in a wind tunnel in full size or moderate scale reduction protruding from a wall. On *The Comet* they play a minor rôle.

The friction between the real car bottom and the ground changes its character behind the point where the boundary layer of the bottom reaches the ground. The boundary layer on a smooth surface traveling at 100 mph grows to a thickness of about a foot at a distance of about 50 ft behind the leading edge and to a thickness of several feet in the rear part of a train. The thickness is, of course, not very well defined as the air dragged along flows in eddies and mixes somewhat irregularly with the air beyond the boundary layer. In the rear part of the train the velocity profile underneath the car bottom is roughly an S-curve whose character depends on the relative roughnesses of the train bottom and the ground.

An attempt was made to duplicate flow conditions underneath the car bottom in a wind tunnel. Experiments were conducted with a rail Zeppelin model of $^1/_{12}$ scale in width and height in the 9-ft wind tunnel of the Guggenheim School of Aeronautics at New York University over a belt moving at 60 mph. This device was developed by A. Klemin. The belt is arranged flush in a recess of the ground board. Except for a small trace of the flow past the leading edge, this belt, when run at a surface speed matching the tunnel wind speed, washes out the boundary layer otherwise built up on a stationary ground board. This was ascertained by velocity traverse measurements. However, both model and belt were too short to show an appreciable drag difference with the belt running and still. Even with several crude projections attached to the car bottom to simulate trucks and accessories, no relative increase of drag when the belt was run was consistently measured. In designing the train, nevertheless, an effort was made to conceal truck accessories as much as feasible in recesses in the otherwise fairly smooth and rounded bottom. During the trial runs some velocity probing was done underneath the car bottom about the truck recesses. The results confirmed the opinion that little of the truck structures protruded into a region of high velocity.

To supply the engines, radiators, and the ventilation system fresh air has to be drawn into the train at certain places and expelled at others. If this is done without any regard to aerodynamics, appreciable parasite drag can be introduced by lost momentum and by disturbance of the air flow over the rest of the train. Here a compromise had to be struck, because the choice of the location of the orifices for air intake and exhaust was greatly limited by restricted space. An interesting study was afforded by an extensive series of wind-tunnel tests with a model equipped with a miniature blower and screens arranged to simulate the flow around radiator fans and through ducts. These experiments were conducted at the Daniel Guggenheim Airship Institute, Akron. They emphatically indicated the benefit which could be derived from louvers with curved guide vanes. One of the models tested is shown in Fig. 26. The information gained in these tests was helpful in designing intake louvers with vanes which are automatically reversed when the train is reversed.

Aerodynamical considerations are not confined to the drag problem. As speeds are increased and weights are reduced the lateral forces from side winds gain importance. For a given shape these side forces are approximately proportional to the forward speed for moderate values of the resultant angle of yaw. When a strong side wind attacks a train from the inner side of a curve it adds to the overturning moment, already caused by centrifugal force, and therefore affects the problems of stability and safety, especially in the presence of oscillations. It was therefore deemed wise to keep the train height low and the roof smooth and to round its edges. Tests were made in the Akron wind tunnel on train models in yaw, as shown in Fig. 27. They gave the lateral air force, the rolling moment, and the yawing moment due to side wind combined with foreward speed.

Another aerodynamical problem was involved in designing the air intakes for the air-conditioning and ventilating system. The system as embodied in *The Comet* was so designed that the exterior pressure distribution is helpful and the natural draft is always in the desired direction, when the train is running even when the exhaust fans are shut off or side winds are present. One of the features contributing to this effect is the peculiar profile of the intake-louver recesses. They were also tested in the Akron wind tunnel and the tests were helpful in arriving at a simple and satisfactory design.

ACKNOWLEDGMENT

In this application of aeronautical-engineering practice to railroad-equipment design and construction, the author has had the close cooperation and material assistance of the following members of the Goodyear-Zeppelin staff: Harry Vissering, railway consultant; Z. W. Wicks, assistant chief engineer; B. C. Baade and H. R. Liebert, project; L. H. Donnell and K. F. Bauch, stress analysis; W. B. Klemperer, research; G. E. W. Mosebach, structural design; H. H. Haines, mechanical equipment; R. F. Bache, power-plant installation; E. L. Shaw, electrical installation; K. Huerttle, decoration; R. A. Hudson and V. W. Coffelt, construction.

The Goodyear-Zeppelin Corporation wishes to express its appreciation to the New York, New Haven, and Hartford Railroad for close cooperation and assistance in the development of *The Comet*. It also desires to acknowledge the assistance of the various manufacturers whose equipment was adapted to the train.

SALVAGE *and* RECLAMATION

By T. H. OWENS

WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY

THE ELECTRICAL industry uses an enormous variety of manufacturing materials as well as a large assortment of expense materials. Elimination of waste in converting manufacturing materials into finished products and in the use of expense materials affords experience in waste prevention and reclamation of interest to those engaged in similar manufacturing fields.

CREATING CONSCIOUSNESS OF WASTE

Much of the waste now incurred could be avoided if all who serve industry would become conscious of it. Several methods have been tried in the Westinghouse plant to stimulate this consciousness. One of these is the use of posters descriptive of waste prevention. Another striking way to develop waste consciousness is to place typical waste materials on display boards and price the various items, thus giving the employees some conception of the cost or selling price of the materials and the tools with which they work. Similar display boards are used to show damaged tools which are not safe to use. This helps in accident prevention and is right in line with waste prevention, inasmuch as personal injury and damage to company property are responsible for much of the waste in industry. Still another method used in our plant is to give cash awards for meritable suggestions for eliminating waste with a cash bonus for every fifth suggestion accepted from the same individual. This makes employees alert to possibilities of savings on manufacturing and expense materials, tools, manufacturing methods, and similar items with which they are directly in contact.

SALVAGING SCRAP MATERIAL

Before undertaking any salvage or reclamation operation, its economy should be determined and there should be no doubt that it will give a net profit reasonably in excess of the value obtainable for the material if it were disposed of as scrap in its present condition. This applies particularly to finished products and assembled parts which must be disposed of because they cannot be sold or used. When the apparatus to be dismantled does not contain parts that should be saved, it is generally more economical to sell it as junk. Of course, where the industry has a well-developed salvage department equipped with torches, shears, skull-crackers, and similar equipment, the dismantling or wrecking cost is more in line with scrap-metal dealers' costs. However, the scrap dealer still has the advantage of lower labor rates than are paid by the manufacturer.

Much can be accomplished by watching the scrap pile and tracing the materials back to their source. Analysis of the scrap-pile contents will suggest much that might be done to eliminate or reduce the amount of such waste. It will show why the materials were scrapped and if the material from which the parts were machined or cut was purchased in the most suitable mill lengths and sizes. It should also instigate the following questions: Can the manufacturing operations be changed in any way that would reduce the scrap loss? Can the material be used in its present condition or with economical modifications on any products or on maintenance work in or about the plant? Can it be sold to any other plant for use at a value higher than obtainable as scrap? If the material has to be scrapped, is it being disposed of in a manner that will bring the best possible scrap value?

Salvaging scrap iron, scrap steel, and scrap non-ferrous materials is an important item of saving, especially in large industries. A plant such as ours at East Pittsburgh is fortunately situated in that it has its own cast-iron and alloy foundries and copper mill for the disposal of much scrap metal after the scrap iron and steel have been reduced to chargeable size by the salvage-department equipment. Scrap steel in excess of foundry requirements is reduced to such sizes as will bring the best price and is sold on the open market. Cost records are kept to show if each operation is justified by a worth-while saving.

Non-ferrous turnings give some trouble because of difficulty in keeping the various grades of metal separate in the machining departments from which they come. These turnings are quite valuable when one alloy is not contaminated with another but their value is very greatly reduced when alloys are mixed. Magnetic separators are used at the foundry for taking out ferrous materials. However, the real answer to this problem is to keep each alloy separate at its source and to deliver it on a guaranteed analysis to the foundry or purchaser. This can be accomplished by the use of small scrap cans located at or near the machines. The cans should be suitably labeled to show their contents and they should be removed promptly from the machining floor when filled. If the cans are not promptly removed when filled, there is danger of contamination. At the alloy foundry, all slag and floor sweepings are reclaimed. The slag is put through a ball mill to crush the metal and is then run over a Wilfley table where the non-metallic materials are washed out. The percentage of metals reclaimed in this manner is quite high and the operation is not costly.

These methods of handling waste materials are more or less common to industrial plants. The metals represent the general run of scrap metals and there is not much that can be done about them except to see that they are handled in such a manner as will bring the highest possible scrap value.

SALVAGING SCRAP CASTINGS

Waste prevention in foundries can be accomplished by divers methods. In our foundry, a daily post-mortem is held by the foremen and the inspectors over the day's accumulation of scrapped castings to determine the nature and cause of casting defects. Action taken to prevent recurrence of such defects has reduced the loss on defective castings to a reasonable minimum.

Another good foundry practice is to check thoroughly and approve the first casting made on a new or changed pattern before proceeding with production on the rest of the order. The casting is carefully checked to the drawing and, if there is a possibility of a porous condition, it is machined and further inspected before releasing production. Incidently, this practice is followed on all machined parts ordered in quantity, whether made on new or old tools and fixtures. The foundry personnel works very closely with the designers and is always consulted when a new casting is being developed. This minimizes possibility of error before the job is placed on a production basis and does much to prevent waste of time and money in the foundry.

Contributed by the Management Division and presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 17–21, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

Intensive study by the metallurgical department has made it possible to increase the scrap content of the various heats by more than 100 per cent and reduce the amount of pig iron accordingly. This has been accomplished with a reduction in the amount of scrapped castings from the heats. The various grades of sand used in the manufacture of cores and molds are now being studied and it appears that this also will bring about a worth-while saving.

WASTE PREVENTION BY STANDARDIZATION

The modern manufacturing plant is of necessity set up to manufacture in large quantities standard products for stock, thereby intensifying waste prevention, salvage, and reclamation problems. In order to procure low costs, sizable quantities of products must be manufactured on each set-up of a machine tool. At the same time, changes in design, supersession, adverse market conditions, and other similar circumstances make it desirable to hold the stock quantities down to small amounts. These items must receive careful consideration when determining the quantities to be placed in stock, and, while there must be sufficient for low-cost production, there must not be more stock on hand than that for which there is a market within a reasonably short time.

Standardization of materials is important from salvage and reclamation viewpoints because it limits sizes, shapes, and varieties of production and expense materials and results in considerable economy. The activity of the remaining sizes increases and they can be manufactured or purchased in greater quantities at lower prices than would apply on lesser quantities. Furthermore, reduction in kinds and sizes of materials decreases the investment in stocks, lowers storekeeping and inspection expense, and minimizes the variety of drills, reamers, gages, and similar small tools used in fabricating finished products. Standardized materials are necessarily applied over a much broader range than non-standardized or special materials. Therefore, when their application is discontinued on a particular product or operation, there is generally enough other activity to absorb the stocks on hand. With unrestricted varieties, the salvage and reclamation problems are quite difficult when obsolescence occurs.

RECLAMATION OF EXPENSE MATERIALS

Expense materials should be given just as much consideration as production materials because worth-while savings can be effected by their standardization. For example, for several years we have been resharpening worn files by a sandblasting process, thus renewing their life four or five times. When the used files can no longer be resharpened by this process, they are sent to outside companies which recut them. This affords considerable saving in an industry the size of ours, which can readily be seen by comparing the average cost of new files at 35 cents with the resharpening cost of only two cents each.

Wiping materials have been given considerable attention at our plants and this has resulted in a saving of more than 50 per cent in their costs. Our former practice was to purchase mill-end wiping cloths and clean cotton waste, all of which were burned when soiled. The cost of mill-end cloths averages about 16 cents per pound, while the cost of waste is about six cents per pound. Tests showed that waste is two-thirds more absorbent than mill-end cloths and therefore waste is used wherever possible. The mill-end cloths which are used are laundered at a cost of three cents per pound, delivered dry by an outside contractor, so that this practice results in a considerable saving. Some companies have found it advisable to use hemstitched high-grade wiping towels because they can be laundered on an average of thirty times as against five or six times for mill-end cloths. The former material costs two and one-half to three times as much as the latter and, where high-grade wiping materials are used, it is necessary to have a checking system by which each towel given out is recorded. In our case it was thought advisable to use the cheaper cloths and operate without incurring the expense of a checking system.

Laundering equipment was installed several years ago at one of our plants and although the installation proved profitable and is still in operation no further installations have been made because volumes of laundering vary with the rise and fall of business and such equipment cannot be loaded consistently. Wiping materials are not given a great deal of consideration as a rule, and the same is true of many other expense materials. A study of these has afforded a saving of many thousands of dollars annually to the Westinghouse Company.

EXAMPLES OF APPLICATION OF INACTIVE MATERIALS

Disposing of inactive materials is frequently difficult, but it is our feeling that there is a place for practically all materials of commercial sizes left on hand because of obsolescence, changes in design, or for other reasons. It is sometimes difficult to find the place or application for such materials but it pays to make the search. For example, we had to dispose of 300,000 yd of special-grade cotton flannel, 52-in. wide, when this material suddenly became obsolete. The flannel was offered to textile dealers who market such goods, but they were reluctant to take the material which was not commercially standard. Finally, the flannel was sold to a dairy company for use in straining milk.

An interesting inactive-material saving was made when a large tonnage of terne plate, purchased for use in the manufacture of drawn electrical products, was discontinued when other more suitable materials were developed. The terne plate was sold to a manufacturer of caskets. Still another saving was made when a large amount of paper became inactive in one of our plants. Upon checking with the paper trade it was found similar material was being sold to a manufacturer of wicker furniture. As a result of the investigation, the entire lot of paper was sold at an excellent price.

The substitution of inactive insulated electric cable for other cable of similar sizes enable us to apply almost all such materials that become inactive in our plants. It is first necessary to convert the number and diameter of wires into circular mils and compare sizes on this basis. We must, of course, be certain that the cable being substituted is sufficiently flexible and that its insulation is sufficient for the voltage it is to carry. Also the insulation must be of the proper type for the intended service. It is of course understood that the cable must be at least equal in quality to that for which it is being substituted and that it is in all respects suitable for the service for which it is to be used. In such cases full value is not obtained for the material, but the percentage of cost recovered is quite high.

All of the inactive and surplus materials at our plants are listed in alphabetical and numerical order in what we call a surplus-material bulletin. Copies of the bulletin are distributed to all storekeepers, purchasing agents, and manufacturing departments at the various plants and service departments, and every one is instructed to make use of the items wherever possible. Many items are substituted for others of similar kind and size, and in this way high values are obtained for them. Other manufacturing concerns located nearby, as well as dealers, are given copies of the bulletin and they purchase some of the materials. Occasionally, items of large value or quantity are advertised for sale in trade papers.

It is sometimes possible to find use for scrap material and thus

(Continued on page 570)

PREVENTION *of* WASTE *and* RECLAMATION *of* MATERIALS

By J. Q. SALISBURY

THE NATIONAL CASH REGISTER COMPANY

A NUMBER of years ago the National Cash Register Company developed a plan to eliminate waste in its plant by analyzing and checking every step in each proposed development of its product from conception to finished form. The benefits of the plan were realized only after years of educational work that has succeeded in procuring the sympathetic understanding of those in whose hands the execution of the plan was intrusted. Schools were conducted and waste-elimination meetings were held to promote the plan. Individual responsibility and penalties were established. Rejection and scrap reports in the form of charts were used. Special suggestion contests were conducted for supervisory forces as well as for bench and machine operators.

ORGANIZATION FOR WASTE ELIMINATION

The plan was developed by appointing committees to pass on all questions affecting the company's product. A committee in the engineering division passes on all contemplated changes in the established line of machines and on every proposed addition to it. A register-examination committee examines the changes after they have been incorporated in complete machine units or plate models. This latter committee is composed of five subcommittees, the names and functions of which are as follows:

(1) The functional committee, made up of representatives from the sales department, passes on each new or changed mechanism to ascertain if it meets the requirements of that particular development.

(2) The manufacturing committee considers the mechanism principally from a tooling and production standpoint. The work of this group results in changes in design, which often means the saving of hundreds of dollars in tools, in processing, and in producing the finished product.

(3) The assembly committee considers the mechanism from a functional viewpoint and studies means for limiting assembly costs.

(4) The inspection and research committee analyzes the mechanism from a functional, operating, and durability standpoint.

(5) The sales-service committee, consisting of trained service men, studies the mechanism from a customer and service point of view.

The findings of these groups are discussed with the engineering division, representatives of which attend all the subcommittee meetings. Should any serious difference of opinion arise, a general meeting of the register-examination committee and the committee from the engineering division is held to settle the question.

In addition to the work of these committees, the research and engineering divisions study drawings of the mechanism and refer to the model or machine unit to decide the proper material to use in the various parts. All materials are ordered to specifications, and when received samples are selected for subjection to chemical and physical tests. When deemed necessary, the research division is furnished with a complete machine unit or a plate model on which to conduct endurance tests.

After the engineering work has been completed, the necessary information and drawings are sent to the planning department where the method of processing the parts is decided and the tools designed. The tools are designed so that a minimum of material will be required and so that wherever possible material will be used that has been salvaged from previous jobs. Tools are standardized and made as foolproof as possible.

All factory-information cards, routing cards, and record cards carried on each item of stock are produced from one master stencil. This prevents the possibility of clerical errors on records used in the process departments and therefore reduces the possibility of incorrectly made parts.

MATERIAL AND PRODUCTION CONTROL

Material and production control is an important item in our business inasmuch as we build 500 different types of machines requiring more than 67,000 parts and 15,000 items of raw material. The ordering of stock in sufficient quantities to keep assemblies moving necessitates constant study to avoid the stocking of large amounts of material made obsolete by sudden changes in design. The vast number of parts carried in stock and the different types of machines built make it impossible, in most cases, to schedule the machines on a daily, weekly, or even monthly basis.

Stock requirements are controlled by daily and monthly quotas which are set the first of each month. The output is based upon sales records, anticipated sales, and consignment requirements. Complete detailed information regarding the number of different types of machines sold, knowledge of seasonal demands, and surveys of general business conditions are also used in setting the limits which are a basis for ordering raw and finished stock. The engineering division keeps the material-control division informed as to contemplated changes so that items of stock to be affected may be liquidated or kept to a low limit.

Orders for new and changed parts are made from the tool lists furnished by the planning department. These lists show the amount and kind of raw material needed to produce each part, and also the time required to make or change the tools required to produce these parts.

Trucking, handling, and storage of parts present a prolific opportunity for waste caused by damage and rust. This waste is reduced by (1) limiting the amount of stock carried in tote boxes, (2) specially designed trays and tote boxes, (3) wrapping parts in paper and rags, (4) plating the parts with rust-resisting metals or coating them with anti-rust compounds, and (5) furnishing operators with gloves for certain work.

When production orders for stock are started in most departments they are handled by the foreman personally and are carefully analyzed and checked with tools and gages as well as

---

Contributed by the Management Division and presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 17–21, 1935, of The American Society of Mechanical Engineers. Abridged.

against drawings to ascertain if all necessary equipment is available and if all requirements of the job are thoroughly understood. The proper equipment to be used and speeds and feeds at which to operate the machines are then ascertained to obtain maximum quality and quantity. The data obtained are entered on departmental instruction cards for future use. All set-ups are checked by the job leader or supervisor before the job is started. All operators are furnished with the necessary instruments and gages for checking their particular operation, time being allowed piecework and bonus operators for periodical checking. This prevents the manufacture of large amounts of defective parts.

ALL DEPARTMENTS HELP

These specific waste-prevention measures lead to the adoption of other measures in various departments of the company. The manufacturing chemical laboratory produces inks, oil and grease compounds, paints, cleaning compounds, glues, and cements of exacting specifications which can be obtained commercially only at peak prices. The research department has charge of operations such as plating, painting and enameling, heat-treating, and copper brazing, thus giving an outside check on the departments performing these operations. The research department maintains a chemist in the plating department to check and maintain plating solutions and to check the thickness of deposits to avoid losses by limiting the possibility of buffing through plates.

In other departments special equipment has been devised to prevent waste. Included among these is a photoelectric cell for controlling the movement of a degreaser for cleaning work. The degreaser is enclosed to prevent the circulation of excessive amounts of air, thereby limiting the vaporization of the highly volatile and costly cleaning compound. In other departments standardization of frames and plating racks prevents waste caused by excessive maintenance and replacements.

PREVENTION OF WASTE BY INSPECTION

All parts are inspected at various intervals during the manufacturing process and the point and number of inspections are determined by the nature and method of processing the parts. A final inspection provides a complete mechanical and functional test of each machine, in spite of the fact that the registers have been inspected previously.

Samples of the first run of all new and changed parts are checked against drawings. If errors are found, the causes are investigated by the planning, tool, or production departments and the necessary corrections are made. In many cases this eliminates the need for expensive gages and inspection operations and indicates the need for additional operations, changes in the design of tools, gages, and fabricating equipment.

Stock rejected by inspectors is returned for correction to the department equipped to do the work. As far as possible it is returned to the department in which the defect originated and the operator responsible is required to repair the piece or make a new one on his own time. Unusual conditions found by inspection of any part are traced to determine their cause, after which corrective steps are taken. Scrapped stock is inspected by foremen before disposition to determine if it can be salvaged.

It is found necessary and practical to make minor adjustments during the assembling of registers to insure proper functioning of the finished product. However, when major difficulties are found, representatives of the inspection division locate the trouble and have the necessary corrections made.

Most of the work in the production and assembly departments is done on an incentive basis. Performance standards set by the standards department prevent waste in time and money by analyzing the quality requirements of each operator's work and by studying the time allowed for performing the work in a manner that will enable the operator to maintain the required quality by the use of gages and other means of quality control. This enables the company to expect only the best workmanship from its employees.

It may be of interest to note that in 1934 the National Cash Register Company produced 223,750,000 parts, valued at $8,000,000, of which parts worth $44,291 were scrapped and others worth $35,746 were reclaimed. The total cost of defective parts, $80,037, was one per cent of the total cost of the parts produced.

RECLAMATION OF MATERIALS

The accumulation of scrap material, centralized at several points by the inspection department, is sorted and prepared for final disposition, either to be reclaimed or to be sold as scrap. It has been found that a little time spent in the proper segregation of various materials is more than repaid in the price received for scrap. As previously explained, the operations necessary to salvage or reclaim materials and defective parts are performed in the regular production departments. Whatever parts are not reclaimed on the time of the operator responsible for the defect are reclaimed on a piecework basis.

The manufacturing chemical laboratory reclaims much material by standard processes or by special processes developed in the laboratory. Some of the materials reclaimed are waste oils and greases, varnish and lacquer, shellac, solvents and cleaners, leather belting, glue composition, anti-freeze solutions, inks, plating solutions, type metals, and other alloys.

Defective paper from large mill rolls is reclaimed by the printing division and is stored and used for miscellaneous purposes. Type metals are kept separate and sent to the foundry where they are melted into pigs, analyzed by the research division, and remelted, and where the necessary metals are added to restore them to their original formula. Stereotype mats are carefully filed so that duplicate plates can be made on reorders.

Other reclaimed items include skeleton steel remaining after first-run blanking operations on punch presses in the production of small parts. Scrap from die-casting machines is reprocessed by adding the materials needed to restore it to formula. Abrasive cleaned from polishing wheels, exhausted sand-blast sand, and slugs from punch presses are used for barrel-rolling of parts to remove burrs formerly removed by more expensive operations. Drills too short for drill-press operations are used on burring machines.

Lumber from packing cases and crates in which materials are shipped to the plant is reclaimed and used in building packing cases for registers and supplies. Practically all of the cases shipped to points within certain freight zones are saved by agencies and returned in quantity lots to the factory, so that some cases are used as many as four times. Scrap lumber of all kinds is run through a wood hog and reduced to fine particles for firing one of the boilers in the power plant. The saving effected by this latter means amounts to approximately $4000 annually.

Arc welding is used extensively to reclaim worn and broken machine parts. Short ends of welding rods are welded together and reused. Savings are also effected by grinding undersize fluted reamers to the next smaller size, by saving usable parts from worn chucks and using them to repair other chucks, and by using screw-machine steel-bar butts in the fabrication of nuts of various sizes. A saving of approximately $30,000 annually is made by reclaiming cutting oil from screw machines

(*Continued on page 570*)

A LUBRICATION PROGRAM

How the Eastman Kodak Company Met Its Lubrication Problems and What Was Accomplished

By VIRGIL M. PALMER and HORACE F. SMITH

EASTMAN KODAK COMPANY

FEW industrial plants have the variety of machinery and processing equipment which is found in the Eastman Kodak Company's plants. Extremes of operating conditions exist such as bearings operating from 40 F below zero to over 400 F above zero. Chemical fumes, abrasive dusts, water, solvents, extremely high and extremely low speeds, and many other factors which complicate the problem, must be overcome.

Within our organization we have many separate and distinct industries. In addition to the large variety of special equipment peculiar to our industry we have commercial equipment such as steam engines, steam turbines, fans, pumps, air compressors, ammonia compressors, generators and electric motors, screw machines, steel-fabricating machinery, printing equipment, paper mills, paper-converting machinery, box- and can-making machinery, woodworking equipment, chemical-plant equipment, lens manufacture, elevators, vacuum cleaners, laundry equipment, office machines, scales, trucks, tractors, conveyers, locomotives, and many other types of industrial equipment.

It is the purpose of this paper to present an outline of the lubrication organization and some of the lubrication practices which have produced worth while and measurable results for the Eastman Kodak Company. The authors also propose to convey an idea of their conception of the scope of lubrication in industry.

EASTMAN KODAK COMPANY'S LUBRICATION PROGRAM

About ten years ago, an investigation was started to determine ways and means of reducing the cost of lubrication. A realization had developed that the purchasing and stores departments were handling too many lubricants. The investigation brought about the development of a lubrication program.

The program incorporated the appointment of a lubrication engineer, the standardization of lubricants and lubricating devices, the development of lubricant specifications for the control of the purchase and dispensing of lubricants, and the development of testing procedure for the selection of lubricants and the control of quality.

As the program developed it was found advisable to schedule definitely the frequency of lubricating service. When recommendations for the lubrication of equipment were issued they included not only instructions for the use of the proper oil and the proper lubricating device, but also a statement of how frequently the equipment should be serviced.

Considerable work was done on the salvaging of lubricants. Methods were developed for the salvaging of turbine oils automotive crankcase oils, and ammonia-compressor oils.

A definite educational program has been undertaken. It is the purpose of this program to convey to those concerned with lubrication information regarding lubricants and lubricating practices which may improve their knowledge of lubrication. This is done through conversations with the operating force and its immediate supervision, through the dissemination of information in the form of printed papers or magazine articles which are circulated approximately once a month, and through the lubricants section in the Eastman Kodak "Material Standards Catalog." (The lubricants section in this catalog furnishes a complete description of each lubricant and gives examples of suitable uses. These catalogs have a wide distribution through the company.)

The difficulties encountered in attempting to standardize lubricants will not be reviewed. It is sufficient to say that most of them were associated with opposition to the replacement of favorite brands of oil and grease with lubricants known only by the Eastman Kodak identification. (Refiners were instructed to mark drums and containers with the Eastman Kodak identification only. Example: EK 8, EK J.)

WHAT THE PROGRAM ACCOMPLISHED

Among the accomplishments was a reduction in machine shutdowns. With improvement in maintenance practices maintenance cost was reduced. Spoilage of the product through contamination with lubricant was reduced. Through the installation of devices and scheduling of service, labor cost for oiling was reduced. The use of proper lubricants effected a reduction in power consumption.

Also, through a study of the lubrication requirements it was possible to reduce the cost of lubricants. This reduction in cost was effected through the installation of devices which economized on lubricant consumption, and through the substitution of common types of lubricants of good quality for high-priced specialties which were not required. The number of lubricants purchased was reduced 70 per cent. This permitted purchase in larger quantities, which favorably influenced the purchase price. The stocking and dispensing of lubricants were facilitated.

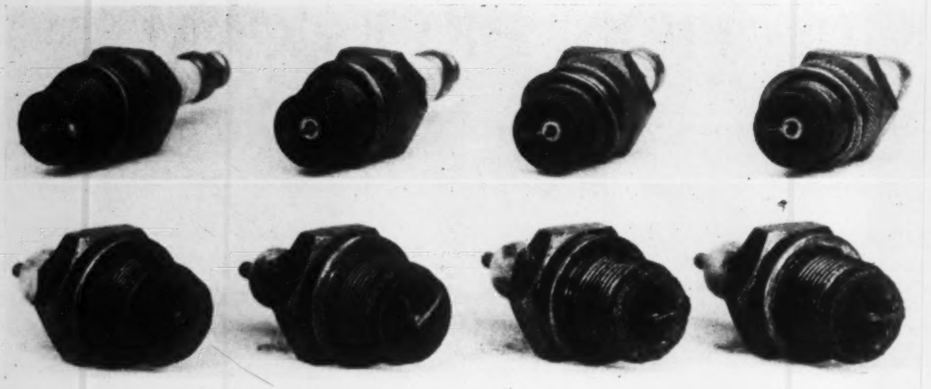
SELECTION AND TEST OF LUBRICANTS

In choosing the best lubricant from a group submitted as satisfying our specifications, we rely upon the performance test to demonstrate the relative quality of the various lubricants. After an examination by our laboratory to determine whether the lubricant meets the physical characterstics embodied in the specification, arrangements are made to run a performance test on one or more pieces of equipment where representative service conditions may be obtained. As our standard lubricants are used on a wide variety of industrial machinery, the performance test is made on equipment which will give the lubricant the most severe test.

As a rule, these tests are quite simple. The parts to be lubricated are either measured or photographed before and after the

---

Presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 17 to 21, of The American Society of Mechanical Engineers.



PHOTOGRAPHS TAKEN AFTER PERFORMANCE TESTS SHOW THE EFFECTS OF TWO TYPES OF AUTOMOTIVE CRANKCASE OILS ON SPARK PLUGS

test to determine any possible wear. Bearing temperatures are taken. Samples of the lubricants are taken before and after the test and are examined by the laboratory to detect the relative change in each physical characteristic. The lubricant which has performed satisfactorily during the performance test and which has shown the least tendency to change during the period of the test is considered to be the most satisfactory lubricant. In our opinion, quality and stability are synonymous.

In testing greases submitted as satisfying our specifications, plain or ball bearings are selected where the appearance of the grease during service may be observed. Once satisfied that the grease will lubricate satisfactorily, the test is continued to determine the relative stability of the lubricant. Tests have been conducted which have required more than a year to show up the relative stability of a group of lubricants.

Our methods of analyzing the lubricants before and after the performance test closely parallel the procedure in the Navy work-factor test. In this test performance conditions are reproduced in the laboratory and the lubricants are analyzed before and after the test period.

We would like to emphasize the fact that although we use specifications to identify and describe the type of lubricant which we require, we do not rely on them entirely in selecting our standard lubricants.

SELECTION OF LUBRICATING DEVICES

The selection of lubricating devices is based upon the reliability of performance, the adaptability to the requirements of the part to be lubricated, and the economy of service required.

In the selection of lubricating devices for plain bearings on such equipment as lineshafts, fans, pumps, and chemical-plant equipment for supplying oil, we find that the bottle oiler and wick-feed cups are satisfactory. For grease we prefer the marine-type grease cup or wing-capped cup and the well-known compression fitting for use with grease gun. For large installations we use either forced-feed lubricators or centralized lubricating systems where many bearings are serviced with oil or grease from one pump.

The chief value of a centralized lubricating system in our opinion is that it provides a control on the quantity of lubricant delivered to the bearings, and the servicing of many bearings is easily scheduled for the oiler. Where cleanliness is of primary importance a measured feed is highly desirable. The centralized system cannot be considered 100 per cent proof against bearing failure. However, it is economical in the use of lubricants and labor and in most cases more reliable than manual oiling. On machines having many bearings even the best of oilers will overlook service points occasionally.

Centralized lubricating systems are carrying lubricants to bearings operating at temperatures which would be very uncomfortable for a human being to service.

It is not difficult to justify the installation of centralized lubricating systems where they apply because of the saving in labor, saving in lubricant, convenience of control of lubricating service, and because of the increased safety obtained.

With the centralized system, we have found that it is necessary to recognize its limitations and to set a scheduled frequency of inspection of the vital parts. We have found parts of the equipment which were inoperative on account of deposits of soap where grease was used and because of broken springs. Through periodic inspection we have obtained reliable performance.

FACTORS TO CONSIDER IN RECOMMENDING A LUBRICANT

In making recommendations for the lubrication of industrial machinery, many factors must be considered. The objective should be to obtain the most satisfactory and at the same time the most economical lubrication. In analyzing the lubrication requirements of bearings on industrial machinery, consideration must be given to the following factors:

(1) Influence of location of equipment
  a Room or surrounding temperature
  b Dust or corrosive fumes
  c Remoteness or accessibility of equipment for service.

(2) Machine operating characteristics
  a Continuous or intermittent
  b Regular day or continuous 24-hour duty.

(3) Influence of production requirements
  a Machine lubricated during operation or during rest
  b Cleaned during operation or during rest
  c Lubricated by specially trained oiler or regular production operator.

(4) Character of bearings
  a Plain
  b Ball or roller.

(5) Provision for lubrication
  a Method of lubrication
  b Lubricating device in use
  c Lubricating device which should be used
  d Location of feed port and number of ports provided.

(6) Machine speeds
  a Effect on selection of lubricants
  b Effect on application of lubricant
  c Effect on devices
  d Effect on oil level or grease pack.

(7) Bearing load
  - *a* Pressure per square inch of projected area in plain bearings
  - *b* Constant or shock load
  - *c* Intermittent or fluctuating loads
  - *d* Change in application of load as in crank-pin bearing of punch press or positive-displacement reciprocating pump.

(8) Provision for retaining lubricant
  - *a* Oil or grease seals
  - *b* Drainage reservoirs
  - *c* Venting sealed bearings.

(9) Condition of bearings and journals
  - *a* Worn or scored
  - *b* Clean or dirty
  - *c* Materials.

(10) Special applications
  - *a* Where no lubricants are required
  - *b* Where use of lubricants is detrimental or prohibitive.

(11) Operating temperature of bearings
(12) Determination of frequency of service required
(13) Selection of proper lubricant.

WHERE TO USE GREASE

One of the first questions which arises is, Shall we use grease or oil? Greases are merely mixtures of oil and soap; the soaps are made by saponifying various animal fats with alkalies in the presence of water. The soap merely acts as a vehicle to hold the oil. The use of grease is recommended for:

(1) Ball bearings operating at speeds up to 3000 rpm.

(2) Bearings operating in atmospheres containing dust or abrasives. Grease tends to seal off the ends of the bearings and protect the bearings against the entrance of abrasive materials.

(3) Plain bearings on general industrial equipment where economy of lubricant consumption can be effected.

(4) Bearings on equipment where possible contamination of the product would be hazardous.

(5) Slow speeds and heavy loads.

(6) Bearings subjected to water or solvent wash.

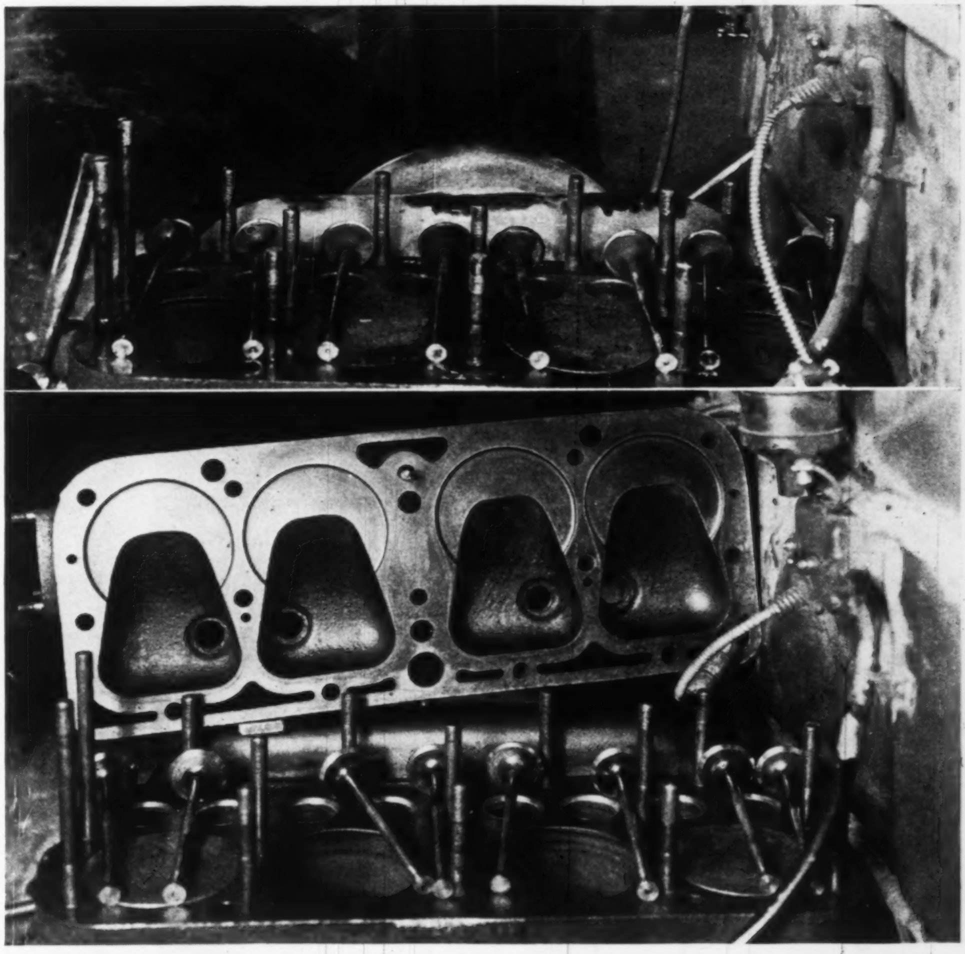
(7) Bearings equipped with devices which will handle only grease.

Although the grease has certain advantages, we prefer to use oil where possible. Some of the disadvantages of grease are:

(1) In our experience we have yet to discover a grease which will not separate and leave an undesirable deposit in the bearing. These deposits may be identified as various soaps of calcium, sodium, or aluminum. Many types of lubricating devices are made inoperative by these deposits.

(2) Where grease is used for plain bearings, the grooves and ports may become clogged with soap and hinder the proper distribution of the lubricant.

(3) Grease is not suitable for the lubrication of roller bearings owing to its inability properly to coat all the bearing sur-



FOR RECORD, PHOTOGRAPHS TAKEN BEFORE (ABOVE) AND AFTER (BELOW) A PERFORMANCE TEST OF AN AUTOMOTIVE CRANKCASE OIL

5

faces. Also, any grit which may be admitted to the roller bearing with the grease is not displaced by the action of the grease but is held in the bearing where it does the most damage.

CHARACTERISTICS OF TYPICAL GREASES

In the selection of the proper grease, we must consider the characteristics of typical greases. For example, calcium-soap greases, or as they are more commonly called, calcium-base greases, are limited in melting point to about 195 F and are not suitable for bearing temperatures of above 120 F. These greases may be used where water is encountered because of the relative insolubility of the soap.

The sodium-soap greases have melting points from 200 to above 300 F. They are suitable for high-temperature work. They are soluble in water and cannot be used where water is encountered.

Mixed-base greases composed of calcium and sodium soaps have been found to give excellent service over long periods of time in ball bearings. Remarkable stability has been shown in greases of very light consistency. These greases may have melting points from 200 to above 300 F.

Aluminum-base greases or aluminum stearate greases are stringy and sticky and will be found satisfactory for certain work where this stringy tacky character is advantageous. They are limited in melting points to about 150 F and are unsuitable for bearing temperatures above 100 F. After melting they have the property of recombining in a homogeneous mixture.

FACTORS IN SELECTION OF OILS

In selecting oils for various applications, it is believed that the problem is more complex. Only a few comments will be made regarding the selection of lubricating oils.

We have been interested to observe that the operating personnel feels safer where heavy-bodied oils are used. We know that in many cases light-bodied oils having a viscosity of 160 sec at 100 F would perform equally as well as oils having a viscosity of 300 or 350 sec at 100 F. Where cleanliness is important and leakage hazardous to the product, we have found that there is a tendency to increase the viscosity to a point where leakage will be largely overcome. This increase in viscosity has nothing to do with the required load-carrying capacity of the lubricant for we know that there are few industrial applications where lighter-bodied oils would not give satisfactory performance. Many will find that they can reduce their lubricant cost by going to oils of lighter viscosity as the price of lubricants usually increases with the viscosity.

It is necessary in selecting the oil to check the pour point of the oil and also the flash point in order to insure its performance at the surrounding or operating temperatures.

At present we have 14 standard oils and 8 standard greases. In addition to these we have a few special lubricants for unusual service requirements.

CYLINDER LUBRICATION

In analyzing cylinder-lubrication requirements of various types of industrial machines the following factors should be considered:

(1) Steam cylinders
  a Character of steam—wet, dry, or superheated. Operating load for Corliss engines, percentage of rated horsepower
  b Temperature of steam
    Below 550 F, compounded steam-cylinder oils
    Above 550 F, uncompounded oils
  c Condition of piston and cylinder walls
  d Manner of feeding lubricant
    Direct to cylinder walls
    Into steam chest
    Into steam line
    Auxiliary feed to valves
    Type of lubricator

(2) Ammonia-compressor cylinders
  a Temperature of gas in cylinder
  b Temperature of gas in expansion coils or coolers
  c Manner of feeding lubricant to cylinder—through lantern gland and rod, direct to cylinder walls, or splash system
  d Provision for trapping oil and possibilities for reclamation

(3) Air-compressor cylinders
  a Temperature of air in compressor cylinder
  b Condition of air lines and valves (deposits of carbon)
  c Condition of air entering cylinders (air filters)
  d Provision for removal of condensed moisture
  e Pressure—high pressures require compounding in some cases above 150 lb.

LIMITATIONS OF LUBRICANTS MUST BE CONSIDERED

In the selection of lubricants it is not enough to consider the qualifications of the lubricants, but it is also advisable to consider and understand the lubricant's limitations. We are using a lubricant which has a service life of six months in heavy-duty speed reducers. We have found that if we allow the oil to remain in service for a longer period of time, the physical phenomena of polymerization takes place and the oil within a few hours will assume the appearance of rubber. The use of such a lubricant might be strongly questioned. Although we have tried many extreme-pressure lubricants and other oils, we have been unable to find another lubricant which will meet the service requirements in a satisfactory manner. This lubricant has an extremely high surface tension and as a result of this it is easily retained in the gear cases.

Extreme-pressure lubricants as a rule have low surface tension and considerable difficulty is encountered in retaining them in the gear cases.

Where we have extreme temperatures or possible contamination of the lubricant, we recognize a limitation to the service life of the lubricant and set up schedules to control the replacement of the lubricant at specified intervals.

SCHEDULING LUBRICATION

As part of each lubrication survey, recommendations are made for the frequency of servicing bearings or machine parts. In many instances lubricating schedules are issued to the operating force. These schedules resemble a monthly calendar on which we indicate what machine parts are to be lubricated each day in the month. The oiler is required to indicate on these charts whether he has serviced the equipment on the date specified. This plan of scheduling and control has been working satisfactorily for several years. The chart acts as a convenient means of reminding the oiler when the various parts require lubrication. Experience has shown that certain types of bearings and groups of bearings can be lubricated according to the following schedule:

Ball bearings on electric motors, once in six months to once per year
Ring-oiled bearings, once per month
Plain bearings, hand lubricated, once per trick to once per day
Plain bearings, bottle oiler lubricated, once per month to once per 2 months

Plain bearings, lubricated by wick-feed cup, once per week to once in 2 weeks
Plain bearings equipped with sight-feed cups, once per day to once per week
Plain bearings equipped with grease cups, filled once per week to once per month
Plain bearings equipped with grease cups, turned down once per day to twice per week
Plain bearings, lubricated by grease through compression fittings, three times per week to once per week
Enclosed gears or speed reducers, attention daily to once per month
Exposed gears, service once per week to once per month
Exposed cams, daily to once in three days.

Lubrication service should not interfere with production. Shutting down machines for lubrication incurs a loss in labor and lost production. In most instances this can be overcome by equipping the machine with proper lubricating devices which will permit servicing the bearings while the machine is in operation.

SALVAGING LUBRICANTS

We are making every attempt to salvage lubricants for reuse where economical.

As we have one of the largest refrigeration plants in the world, we recognized a few years ago the possibility for reclaiming the used ammonia-cylinder oil. Although attempts were made to obtain information with regard to past experience with the reclamation of ice-machine oil, we were unable to find any users whose experience would be beneficial. We found references which advised against the attempt to reclaim ammonia-cylinder oil. After considerable testing, we decided that we could reclaim the ammonia-cylinder oil by aerating the oil to remove the ammonia, heating, and centrifuging. The reclaimed oil after several reclamations changes only slightly in physical characteristics. The viscosity, flash point, and fire point were practically unchanged. The pour point was slightly higher, about 5 F, but this was not enough to affect lubricating value.

Automotive crankcase oils are being reclaimed by the use of a standard crankcase-oil purifier. This consists of an electric still which drives off the moisture, gasoline, and volatile constituents and a filter which removes undesirable foreign materials from the oil. This oil is checked periodically for tendency to corrode metals of construction, for presence of volatile substances and for organic acidity.

Steam-turbine oils which are removed from the systems when the oil reaches a neutralization number of 0.8 per cent are delivered from the turbine system in a clean state. These oils are classified according to color and condition and dispensed to our various departments for general-purpose lubricants.

Some gear lubricants are filtered and returned to the gear cases for continued service.

MARKED FOR STORAGE

All standard lubricants are known by an EK number. Suppliers of lubricants are required to mark all drums with the EK number and the specification number. No lubricants are delivered to storage until they have been tested and passed by our laboratory.

DESIGNING FOR LUBRICATION

The designer of equipment is primarily interested in the kinematics and mechanics of the machinery and becomes so interested in this phase that he overlooks, in many cases, factors which are of utmost importance to the industrial user of equipment. The designer should be conscious of the scope of lubrication while working on the design. In providing for lubrication of the equipment he should be aware of the cost of labor for oiling, and should design the bearings to prevent leakage of lubricant and to provide for inspection of the bearings and proper distribution of the lubricant within the bearings. He must consider the most satisfactory lubricating device from the standpoint of labor economy and reliability of operation, and he should also provide for possible changes in lubricating devices to meet the customers' needs.

Too often through oversight or in the interests of economy no provision is made to permit the oiling of the machine while running. In this case the purchaser or user of the equipment is obliged to run tubing from the bearings to a suitable location to permit lubrication while the machine is running.

Strange as it may seem, some designers are satisfied to provide only oil holes as a means of supplying lubricant. By the time the equipment is painted the holes have almost disappeared. If we desire to install lubricating devices we must take down the machine to drill and tap the bearing. Steps should be taken to standardize on tapped holes for all bearings. This would enable a purchaser to change lubricating devices if he believed it advisable.

As to grooving of bearings, usually a single groove will serve just as well as the fancy geometric designs so often provided.

Occasionally we find no provision made for venting bearings and gear cases. Also, inadequate provision may be made for draining and cleaning gear cases.

In many industries cleaning costs are high. Protection of the product from oil spatter is of vital importance. Even in rough work oil leakage is wasteful and unnecessary, if consideration is given to it at the time of the design.

The designer must appreciate the fact that no oil company has been able to produce a lubricant which will overcome troubles caused by incorrect design. It has been our experience, without exception, that where we have tried many lubricants to prevent bearing failure or destruction of gears and all have failed, the lubrication problem became simple and usually the original lubricant proved satisfactory when we corrected the design.

In following the trend of speeds and compactness of mechanism, the designer would do well to rely on his own observation of the performance of various lubricants over extended periods of time and under comparable service conditions, before attempting to rely on the claims of manufacturers for the lubricating qualities of their products. Attempts to reproduce operating conditions in the laboratory have not been altogether satisfactory.

LUBRICATION AND MAINTENANCE

All the work of selecting the proper lubricants and providing the proper lubricating devices will be a total loss unless the lubricant is supplied to the bearing. Most failures of bearings are the result of lack of lubricant rather than the use of an improper lubricant. To provide for satisfactory lubrication service the oiler should be given specific instruction as to what lubricants to use on each part, how frequently the parts should be lubricated, and what adjustments should be made to lubricating devices. He may also be informed of the time allowed for completion of the task.

CONCLUSIONS

Outstanding among the problems arising from any attempt to organize lubrication is the problem of solving the cause of bearing or machine wear or failure. It has been our experience that no matter what the cause may be, failures of bearings or equipment are usually attributed to the lubricant. In many instances laying the failure to the lubricant is an unintentional but convenient alibi. It should be a definite part of any lubrication program to educate the operating force so that their approach to lubrication problems will be analytical. Often it is so much easier to say, "It's the oil—throw it out and get some good oil," than it is to check the alignment, the operation of the lubricating device, or to locate the real trouble.

Among the causes of excessive wear or failure which are often responsible for the condemnation of the lubricant are: Misalignment, wrong materials of construction, contamination of the lubricant, overloading equipment, use of dissimilar metals (producing so-called galvanic action), failure on part of operating force to recognize limitations of the lubricant, eccentricities which develop in the machine with wear or changed operating conditions, use of wrong lubricant, and poor workmanship in making repairs and adjustments to machine.

After several years of examining and testing lubricants we have reached the following conclusions:

Where conditions permit, oil is preferable to grease.

The use of graphite on industrial machinery is justified in but very few cases. We are using graphite greases for bearings on centrifugal pumps handling hot water, solvents, and acids.

One hundred per cent Pennsylvania motor oil is not best for all service requirements.

Recommendations for lubrication by manufacturers of equipment are not always satisfactory.

As a class, we question the claims for extreme-pressure lubricants, cutting oils, and many of the so-called special lubricants.

Although the selection of the proper lubricant and the provision for proper application are important and should be given first consideration, experience has shown that most mechanical failures are due either to lack of lubricant, adverse operating conditions, or mechanical faults.

In hand oiling, the best of oilers will miss some of the bearings.

Control of lubricating service by definite schedule is preferable to relying on the oiler's judgment.

Ice-machine cylinder oil can be reclaimed and re-used.

Lubricating devices which create a constant pressure on grease will cause the soap to separate from the oil—in many instances making the device inoperative.

No single laboratory testing machine which has as yet been developed to reproduce performance conditions tells the whole story.

Mechanical faults cannot be cured by lubrication.

Satisfactory lubrication depends upon an appreciation of the limitations of each lubricant under the actual service conditions.

There are still evidences that designers of industrial equipment in many instances have been so greatly interested in the mechanics and kinematics of machinery that lubrication of the equipment has been practically an afterthought.

Oilers should not be allowed to mix lubricants to obtain some fancied improvement in quality or performance.

The refiners cultivating the industrial field are producing lubricants to meet the requirements of industry and are furnishing gratis a high type of engineering service.

The foregoing statements should be considered as the opinions of the authors who recognize that many will disagree with certain statements. The authors also recognize that despite the large number of lubricants which have been examined by them, this number represents but a small fraction of those on the market.

Salvage and Reclamation

(*Continued from page 562*)

dispose of it to a good advantage, as shown by our experience with broken and defective porcelains. Some years ago the idea of bedding pipe furnaces with scrap porcelain was conceived, and all such material at our ceramic plant was sold to pipe manufacturers for between five and six dollars per ton. Prior to disposing of the porcelain in this manner, it was hauled to a remote burial place at considerable cost. Unfortunately for the ceramic business, the pipe manufacturers now use electric furnaces extensively and the scrap-porcelain outlet is quite restricted. However, the illustration should serve its purpose.

Reference has been made to the use of welding in reclaiming defective castings. This same process can effect savings in many ways, including the fabrication of jigs and fixtures which at the same time provides an outlet for many short ends and centers of steel bar and plate which would otherwise have to be scrapped.

The shredding of scrap paper for packing purposes is of fairly recent origin, but this material is already replacing wood excelsior to a great extent. This provides an outlet for a waste material which formerly was burned or sold to scrap-paper dealers at a very low price.

Expense materials have not been mentioned as specifically as production materials, but this does not mean that they are of lesser importance. Savings can and have been effected by such simple things as decreasing the width of stenographers' notebooks and replacing old-style lead pencils by refillable pencils. Savings are also obtained by using a single form or piece of paper for ordering and recording, and by providing duplicate copies by hectograph or mimeograph, because by their use, less clerical work is required, errors of transcription are eliminated, fewer forms are necessary, and work is expedited.

When considering the salvage or reclamation of waste materials, the thought of making it impossible for such materials to come into being should always be kept in mind. No waste should be accepted as unavoidable, but rather, every effort should be made to dry up its source. It must be remembered that custom and habit do not make anything right and the fact that there have always been large accumulations of scrap materials does not mean that we must continue to have them. An ounce of waste prevention at the source is truly worth many pounds salvage and reclamation.

Prevention of Waste and Reclamation of Materials

(*Continued from page 564*)

by means that involve the use of a centrifugal and filtering process.

In the finishing and enameling departments, worn-out graining rolls are reworked and used as bench pads on which to support parts while operators are working on them. Empty paint cans are cleaned and sold to employees. Waste paint and lacquers are accumulated and sold for use on rough work. Masking tape used to cover chrome-plated high lights during finishing operations on the registers was formerly used once but is now made into forms and used several times.

These are examples of some of the principal materials reclaimed. There are many others and although some of them are of a comparatively minor nature they aid in effecting a considerable saving each year.

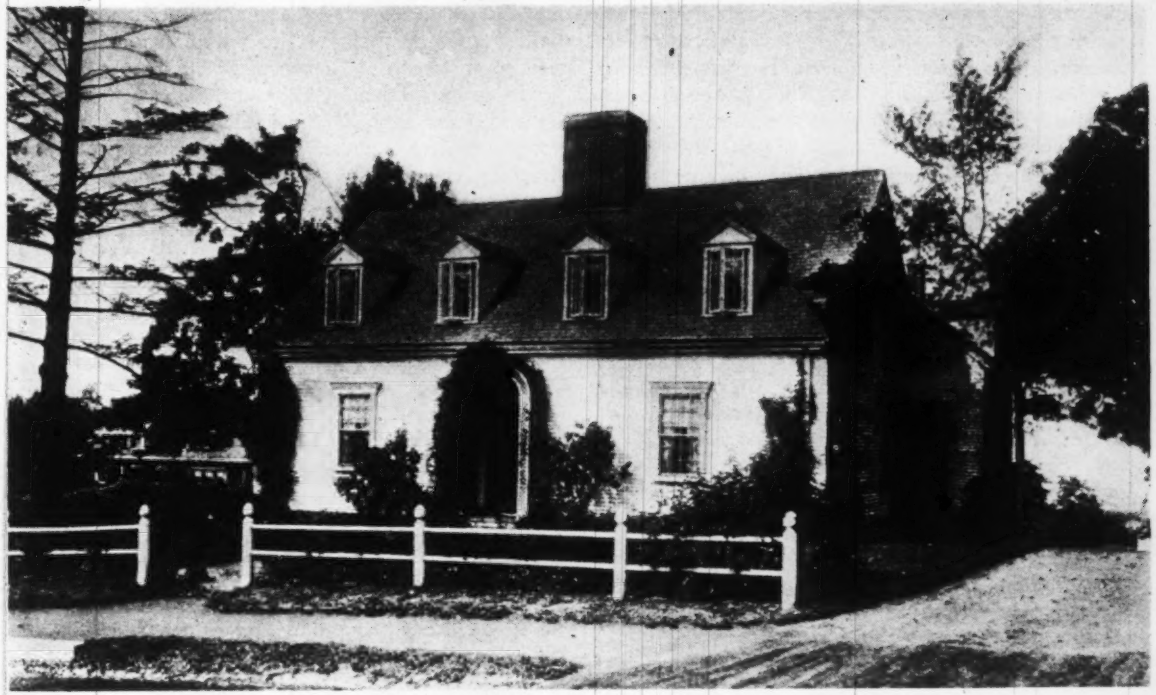


FIG. 1 TYPE OF HOUSE THAT LENDS ITSELF TO PREFABRICATION

PREFABRICATED HOUSING

Abstracts of Papers Comprising a Symposium Held at the A.S.M.E. Cincinnati Meeting

DURING the Semi-Annual Meeting of the A.S.M.E. held at Cincinnati, Ohio, June 17 to 21, a session was devoted to the subject of prefabricated housing, a development that has been of growing interest to engineers. The papers presented were: "Financial Aspects of Housing," by Ross F. Tucker[1] and Albert Dietz;[2] "The Federal Housing Administration and Recent Developments in Dwelling Construction," by A. C. Shire;[3] "Recent Trends in Housing," by H. H. Keller;[4] "Plywood and Prefabricated Plywood House Units," by Thomas D. Perry;[5] "New Methods of Construction for Prefabricated Houses," by Charles B. Norris;[6] "Prefabricated System, A New Departure in All-Wood Housing," by G. W. Trayer[7] and J. S. Mathewson;[7] and "Mechanical Units for Houses," by D. C. Slipher.[8]

These papers evoked considerable interest and discussion, but because of their length it is not feasible to publish them in their entirety. Hence, only a review of their predominating features will be given here. Generally speaking, the papers covered the economic aspects involved in the prefabrication of houses, the developments and advancements which have been made in the construction of houses and home equipment, and specific types of prefabricated houses and equipment which have been designed for production on a quantity basis and erection at the building sites at minimum cost.

The trend in the prefabrication of houses is toward the establishment of standard house designs, the main structural parts of which are subassembled in the factory before shipping to the building site. The subassembled parts are reproduced in large quantities, thereby improving construction efficiency by applying mass-production principles. The objective is therefore to do more work in the factory and less work in the field with the consequent reduction of labor costs and the elimination of much of the waste accrued when constructing houses on the building site. However, some engineers are of the opinion that since lumber, millwork, masonry units, and mechanical equipment for houses have been subjected to a close study in so far as standardization, prefabrication, and low shipping costs are concerned, the problem in low-cost house construction is one that involves the most efficient methods of assembling these units at the building site.

While much of the present experimental work in connection with prefabrication is to be commended, H. H. Keller pointed out in his paper that several defects are apparent in present designs of prefabricated houses. Summarized, these are: (1) Ultramodern designs and fads for which the average man has not been educated create sales resistance on the part of a prospective buyer; (2) the introduction of many labor-saving devices and home conveniences, the operation and maintenance of which are far beyond the means of the average family, as well as the inclusion of many items the average family already owns and therefore are mere duplication, all tend to create unwarranted increases in the cost of prefabricated houses; and (3) prefabricated houses now on the market sell for as much if not more than the average home built by the former method of construction. However, prefabrication is a substantial movement toward modernizing and improving the methods and materials employed in house construction, and through it much can be done to reduce the cost of housing, the construction of which is now limited by land and financing costs, duplication of profits, and heavy selling expense, these factors being the ones that keep the cost of home ownership high.

---

[1] Professor in Charge of Civil and Sanitary Engineering and Building Construction, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Assistant, Department of Building Construction, Massachusetts Institute of Technology.

[3] Chief Engineer, Federal Housing Administration, Washington, D. C.

[4] Engineer, Bitting, Inc., New York, N. Y. Mem. A.S.M.E.

[5] Consulting Engineer, Jasper Houses, Jasper, Ind. Mem. A.S.M.E.

[6] Director of Engineering and Research, Haskelite Manufacturing Corp., Grand Rapids, Mich. Mem. A.S.M.E.

[7] U. S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wis.

[8] Head of Research Department, Houses, Inc., New York, N. Y.

ECONOMIC AND FINANCIAL CONSIDERATIONS

The housing problem for the 28 million families in the United States taken as a whole can be divided into three parts: (1) The housing of approximately 8 million families with annual incomes greater than $3000, (2) the housing of 14 million families with annual incomes between $1500 and $3000, and (3) the housing of 6 million families with incomes of less than $1500 a year.

According to Mr. Keller, the potential mass market for prefabricated houses must be developed among the 14 million families with annual incomes between $1500 and $3000. His analysis of the normal earning power and financial resources of this group indicates a price limitation for homes costing between $1500 and $3000, with 6 million in the $1500 class, about 3 million in the $3000 class, and approximately 5 million between these two, with a price limitation around $2250. If one-third of the value of homes is allocated to land value and selling and financing expenses, the house-structure values in this potential market will be 6 million at $1000, 5 million at $1500, and 3 million at $2000. Because many families in this group now own an equity in existing homes and many others will purchase a now existing structure, and because competition with local markets and natural prejudices against innovations will create heavy sales resistance, there will be a still further reduction in the demand for prefabricated houses. Mr. Keller concludes that in view of these facts the potential market in this field should be in the class of houses costing between $1000 and $2000, and that optimistic forecasts of the annual volume should not exceed 100,000 units.

FINANCING OF LOW-COST HOUSING

Regarding the housing of this group, Professors Tucker and Dietz in their paper stated that the mortgage relation in which the mortgage represents the real value of the house and the home owner's saving represents the speculation value is an economic menace. If the people in this group are to have homes at all they should pay for them out of income and not out of savings. Furthermore, they must be given security in the possession of their homes, and their equity must be safeguarded against the exigencies of death, illness, and unemployment. The potential market represented by this group can be developed if the building industry will eliminate speculative profits and be satisfied with a fair and reasonable profit for service performed. This can be done, in the opinion of Professors Tucker and Dietz, by a community plan under which the building is done on a quantity and quality basis under centralized control with an arrangement for instalment buying and group insurance that will spread the financial load over a long term of years, provide the home buyer with security in the possession of his home, and keep his equity always liquid. Furthermore, by making the monthly instalment which the home owner pays about one per cent of the cost of his home, a savings fund can be accumulated that will provide not only a cash guarantee fund to protect the underlying debt until it is fully liquid, but a cash payment with which the home owner, at the end of the term when his house is fully paid for, may rehabilitate his house and bring it up to date. Such a plan will provide absolute security, according to Professors Tucker and Dietz, both for the original investment and for the home owner, a condition that has not heretofore obtained in the development of real property, and furthermore, it will stabilize property values and eliminate blighting. The factors in the operation of the controlled community plan and its advantages are enumerated as follows:

(1) Low-cost land because of no unearned increment; a fifth to a third of an acre being alloted to each home.
(2) Low-cost building through standardization, quantity buying, and quantity production, while preserving wide architectural differentiation.
(3) Instalment buying over a period of years.
(4) Group insurance against the exigencies of death, illness, and unemployment.
(5) No mortgage relation.
(6) Security in possession of the home.
(7) Ability to sell without sacrifice.
(8) Stability and permanency of property values.
(9) Prevention of blighting.
(10) Monthly instalment includes all costs.
(11) Transfer of ownership from one community to another without loss of equity.
(12) A cash savings fund at the end of the term for rehabilitation.
(13) Centralized control through a savings bank.
(14) Absolute security of original investment pending liquidation.

The proposers of this plan state that in considering the construction of the house of lowest cost, the building industry should look to the automobile industry and ask first: Why build houses for permanency? The problem of the construction of the low-cost house is not merely that of building a house that will be within the financial range of the lower-income group, but one that will continue in good condition with little depreciation for a period of 25 years, and then may be replaced or rebuilt with a maximum salvage, or in other words, a house that may be refunded within the period of the financial set-up without undue burden upon the home owner.

MACHINERY AND MATERIALS IMPORTANT

Professors Tucker and Dietz also advanced the opinion that a second lesson may be learned from the automobile industry by making maximum use of the machine in the manufacture and assembly of houses. This calls for an entire revision of constructional methods now in use in building houses, and a change from handwork to machine work in the use of materials. The production of low-cost housing then becomes a challenge to all manufacturers of materials but, at the moment, the house of lowest cost will be built of a combination of materials best suited to meet the structural and technical requirements. Masonry materials, such as brick and concrete, have not yet been put in a form to meet the desired economies, although they are within the low-cost range. A structural frame of wood, steel, or other suitable metal is the first step, and the choice of these materials depends upon just what objective is to be obtained. Wood and steel are both acceptable materials if suitable protection is secured and at the moment it is easier to secure the protection with wood than it is with steel, although when wood is chosen it should be used in a very different manner from that in which it is customarily used.

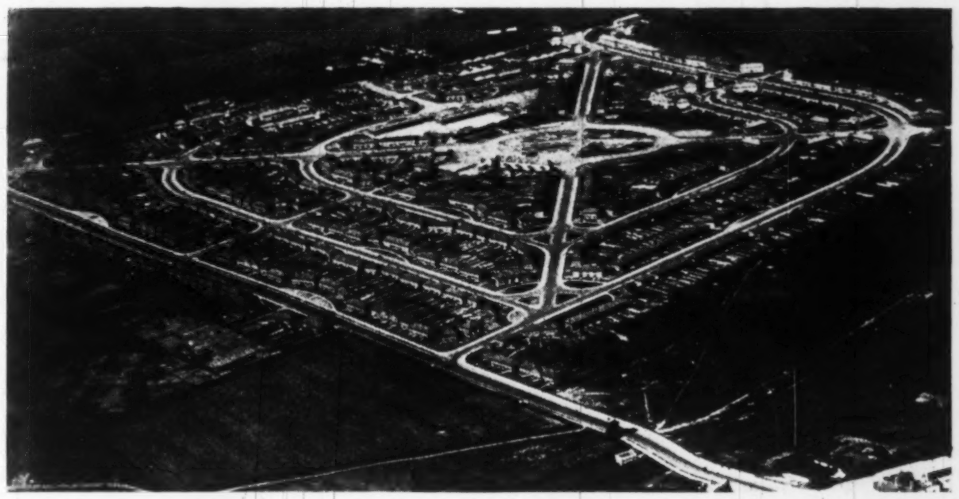


FIG. 2 A PLANNED LOW-COST HOUSING COMMUNITY IN BIRMINGHAM, ENGLAND

Professors Tucker and Dietz reported that a strong, durable, and attractive house of five rooms can be built on a third of an acre and sold for $2500, including the cost of the land. Such a house will be of superior construction, substantially free from deterioration if treated with reasonable care, and should have an economic life of 25 years, when it may be renovated or rebuilt. In order to obtain the economies in cost that the problem demands, such housing should be built in large groups by responsible building organizations which can take advantage of shop fabrication and quantity production. Field work should be limited to the mere assembly of manufactured parts and to decorations. The type of house that lends itself to such construction is shown in Fig. 1. Fig. 2 shows a properly planned low-cost housing community in Birmingham, Eng. Such houses, in the opinion of Professors Tucker and Dietz, could be sold over a spread of twenty-five years, by the payment of $35 per month.

FHA INVESTIGATION OF DEVELOPMENTS IN HOUSING

A. C. Shire devoted a considerable portion of his paper to a discussion of the work of the Federal Housing Administration and its investigations into the recent developments in dwelling construction such as strap-steel structural members, frameless houses, and prefabricated material and equipment for house construction. He stated that although much thought had been given to the prefabrication of houses and materials, and models had been built and panels tested, very few buildings had actually been erected and still fewer had stood the test of time; and what was more important commercially, they had not yet demonstrated that they would be low in cost, practical, and marketable. He pointed out that the greatest advances have been made commercially in heating, air-conditioning, plumbing, and electrical equipment.

Regarding the types of houses which have attained commercial production, Mr. Shire said that manufacturers have been so hampered by the lack of market and by their inability to gage the market they have not been able to produce such buildings in quantity nor to plan production. This has hindered the development of prefabricated houses and the reduction of costs, since the latter depends upon quantity production of both materials and the assembled houses. In almost every case the new materials and methods of construction have cost more than those which have been customarily used. In continuing, Mr. Shire reported that in general the construction cost of a building is about 70 per cent of the selling price of land and building, of which 50 per cent is for the structural enclosure and 20 per cent for equipment and accessories. In examining these items for savings which might be made through a wider application of factory fabrication methods, he pointed out that the present trend is to increase the amount of equipment and accessories and that any reduction in cost therefore must come through a reduced cost of the structural enclosure. A saving of 20 per cent in the cost of this item would show up as only 10 per cent of the selling price. Through efficient and concentrated management and purchase of materials, Mr. Shire is of the opinion that an additional 5 per cent saving in the selling price might be realized. If any such savings are now made, he continued, they appear to be more than offset by the unfamiliarity of labor with the materials and methods used, by the tendency to increase equipment and accessories, and by the distribution of overhead expenses over limited production.

RECENT TRENDS IN HOUSING[9]

Mr. Keller, in addition to the comments referred to at the beginning of this article, pointed out that all housing construction falls into two general groups, (1) the frameless structure in which the same members perform both structural and closure functions, and (2) the framed structure in which the structural members are independent of the closure members but in which the closure members depend upon the structural members for support. By the nature of the materials involved, that is, the bulk required and the type of seal necessary in erection, the frameless house does not lend itself to the development of fabricating methods to the same degree as the framed house, and for this reason the unit-panel construction discussed in this abstract is confined to the framed type of building.

In unit-panel construction, the spans encountered in small and medium-sized houses or buildings, involving relatively small or medium-sized rooms, are taken as the practical unit. This construction divides the wall space, in which both inner and outer walls are treated as one element, into units which are used as bearing or structural elements in the building. By this means forces are divided and distributed to eliminate heavy structural members and the units are designed so that structurally they are but little heavier than closure members in the conventional type of house construction. Under the unit-panel method, outside vertical members of each panel sustain one-half the load carried by the members made up at the point where two panels are united. The closure material of the panel unit, without regard to the structural function which the frame fulfils, is one that contains bulk rather than strength. Waterproofing, windproofing, heatproofing, coldproofing, soundproofing, rigidity, and mass are of more importance than structural strength in fulfilling the closure function. The closure material is attached to the side of the panel frame by approved fastenings.

---

[9] An abstract of the paper by H. H. Keller.

The two vertical members of each panel carry the floors and the roof, and are attached to each other by girt members perforated to receive bolts or approved fastenings for attaching the floor and roof panels. In this manner, a frame is made up and covered to present a complete unit of wall space, including both surfaces, which can be combined with other units to form the complete structure. The units are combined by placing the panels side by side with vertical members of trapezoidal cross-section. The tightening of the fastening bolts, which are perpendicular to the diagonal faces of the panel members and the vertical member of trapezoidal cross-section, tends to align the panels into a position that forms a straight wall. The panels for roofs and floors are also treated as a unit, and are built up in the same way as the wall panels. Gable and hip roofs are of similar construction, varying only in so far as supporting members are concerned. All panels can be designed with openings for doors and windows. Doors may be hung and hardware actually installed, and double-hung or casement windows completed, before delivery to the erection site.

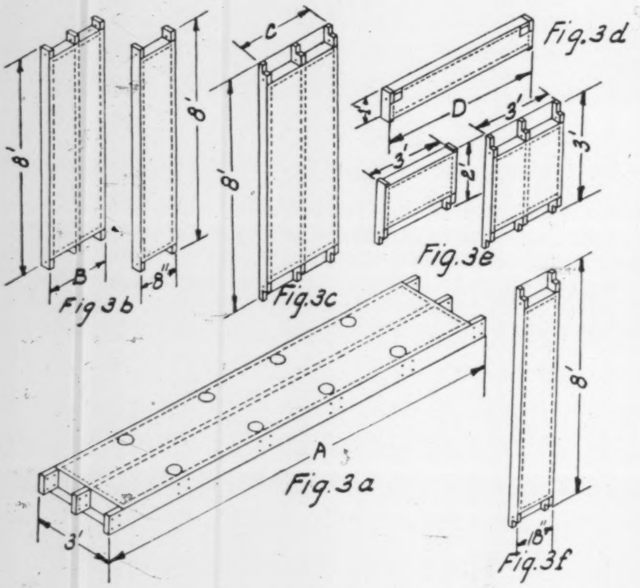


FIG. 3 ASSEMBLY UNITS FOR A PREFABRICATED HOUSE
[Floor Units (3*a*)—Exterior Wall Units (3*b*)—Interior Wall Units (3*c*)—Interior Cap Units for Doors and Archways (3*d*)—Exterior Cap Units for Windows and Half-Story Unit for Return Stairways (3*e*)—Half Unit for Centering Windows (3*f*).]

Unit-panel houses of this design can be erected, exclusive of land, at a cost of less than $300 per room and are adaptable to any of four general styles of architecture. Such houses can be expanded at low cost and can be so constructed that all modern labor-saving devices and conveniences can be installed.

PLYWOOD HOUSE UNITS[10]

There is no doubt but that much of the customary hand cutting and fitting, nailing, and other unmechanized fieldwork now involved in house construction is indefensible and uneconomical. This difficulty has been accentuated by endeavoring to protect and maintain high wages and short hours for building tradesmen. This field situation has focused attention on the practicability of transferring considerable portions of hand-erection work from the field into the factory where the labor problem is less acute and modern machine manufacturing methods are available. Therefore, there is a strong tendency to shift building activities toward the use of more factory-made products and to reproduce correspondingly the amount of fieldwork required. However, the transfer of the same operations from field to factory without change or modification is not justifiable. Rather there must be developed a distinct improvement in the quality and serviceability of the product in order to make the transfer defensible. Such an improvement would be the substitution of weatherproof plywood for nailed rough lumber.

Factory-made products are necessarily reduced to standards that should be adaptable and progressively improved. One evidence of this is the government standardization of sizes and shapes for all primary lumber products and the standardization of piping, plumbing, heating, and lighting devices and fixtures. The impending transfer of former operations employed in house construction into the factory will undoubtedly force the standardization of larger elemental house units, and this is proper since the mass-housing projects under consideration are not designed to meet the requirements of any individual family, but rather to supply improved housing facilities of reasonably assorted sizes for those whose economic status has heretofore barred them from any but the most primitive houses, badly designed and underequipped.

The transfer of former construction operations from the field to the factory will eventually result in the establishment of standard house units for walls, floors, corners, windows, and doors. These individual units should be completely assembled as units in the factory and made ready for erection in the field on a plan that facilitates uniting them together with splines, bolts, nails, screws, and other recognized connectors for wood parts. Up to the present time the use of plywood in constructing these house units has been limited by a lack of a thoroughly waterproof adhesive. However, a new resin-glued plywood is now available for all types of construction purposes that overcomes this limitation. A careful study of the manufacturing and shipping requirements of these house units leads to a conclusion that wall and floor units 3 ft wide meet structural conditions adequately, and give more advantages than narrower or wider units.

DETAILS OF STANDARD UNITS

In the prefabricated house herein described, the plywood sheets which form the inside and outside faces of the wall units as well as the upper and lower faces of the floor units, are firmly glued to both sides of the structural framing, thus becoming a definite part of the load-carrying system. The design of the wall and floor units utilizes the "stressed-covering" principle that has been successfully applied in aircraft construction to secure strength and lightness, making it possible to reduce substantially the size and weight of framework members without sacrificing strength or rigidity.

The floor units, Fig. 3*a*, are made in 3, 6, 9, 12, 15, and 18-ft lengths (dimension *A*), these sizes being used so that identical wall units will be equally suitable at the side as well as at the end of the floor units. In order to give adequate strength without objectionable deflection, the floor units are set on $7^{1}/_{16}$-in. joists, which with a plywood ceiling $^{5}/_{16}$ in. thick and a plywood subfloor $^{5}/_{8}$ in. thick, give a total thickness of 8 in.

The height of each story between subfloor and ceiling has been set at 8 ft, this standard resulting in a wall unit 3 ft wide and 8 ft high, based on the conventional 2 by 4 studding. It has been found advisable to have certain other standard widths such as 2 ft 8 in. where one wall unit overlaps another, as well as 18-in. sizes for half units where it is desirable to center doors, windows, stairways, and entries.

---

[10] An abstract of the paper by Thomas D. Perry.

The methods of assembling the interior and exterior-wall units are slightly different. The exterior-wall units, made in 32-in. and 36-in. widths (dimension *B*, Fig. 3*b*), have upward and downward stud projections as shown in Fig. 3*b*. The interior-wall units are made in 18, 28, 32, and 36-in. widths (dimension *C*, Fig. 3*c*) and are practically identical with those for the exterior walls except that the studs are cut off on the floor and ceiling lines as shown in Fig. 3*c*. The plywood on both sides of the interior-wall units is the same length with a 4-in. space at the top and bottom for access while bolting the units together. The plywood on the interior side of the exterior-wall unit is the same size as the interior-wall unit and has the same bolting clearance. The outside plywood, however, runs the full length of the studs to avoid an exterior gap, and exceeds the standard plywood limit of 8 ft to provide a scarfed or weather-sloping plywood joint over the cross stud. With this construction, all bolting is done from the inside.

It has been found desirable to design a series of interior cap units 28, 32, 36, and 72 in. wide such as shown in Fig. 3*d* (dimension *D*) to accommodate various-size doors and archways. In addition to the standard full-length exterior-wall units, it is necessary to provide for window-cap and base units of standard width as shown in Fig. 3*e* to go above and below standard-size windows. A half-story landing of standard 3-ft width and half-story height with projecting studs, Fig. 3*e*, is required for return stairways. All the units are assembled with the aid of galvanized-steel angles, clips, and connectors having square holes to fit the shank of carriage bolts.

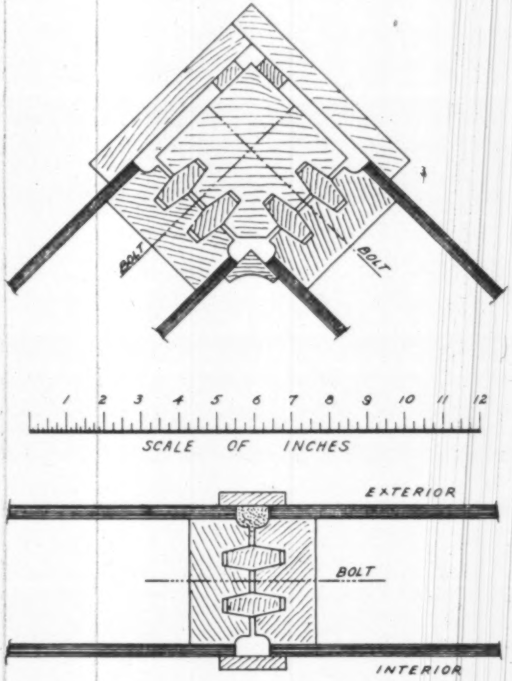


FIG. 4 CORNER JOINT (ABOVE) AND JOINT BETWEEN WALL UNITS (BELOW) SHOWING TAPERED SPLINES FOR DRAWING ALL SURFACES EVEN AND FLUSH

The floor units, interior-wall and exterior-wall units, half-story units for stairways, interior-cap units, exterior-cap units, corner posts, and metal connectors are the principal parts that will be made in the factory. There is a total of 21 different units of which less than half will be used in any substantial quantity in the prefabricated house under consideration. The result is an ideal factory manufacturing program that can be adapted to progressive chain assembly.

PROVISIONS FOR ASSEMBLY

Special provision has been made to center the wall and floor units by using tapered splines to keep all surfaces even and flush and to make the exterior walls tight and waterproof. Approximate details of the grooves and splines on the studding, corner posts, and joists are shown in Fig. 4. The field assembly of the units demands adequate strength and stability and also convenient methods of joining the units together. In the case of the interior-wall units, Fig. 3*c*, the end of the stud is halved off so that the shoulder rests on the joist and the downward extension meets a corresponding upward extension of the stud in the lower wall unit. The joist is extended beyond the nominal length to have adequate bearing on the shoulder of the wall stud below as well as to carry the wall unit above. This extension of the joist beyond the inner face of the stud permits the use of a rigid straight-angle connector between the upper and lower wall units and the joist. A typical joint is shown in Fig. 5. The extension from the shoulder of the stud upward and downward leaves a small gap in which a Z-shaped

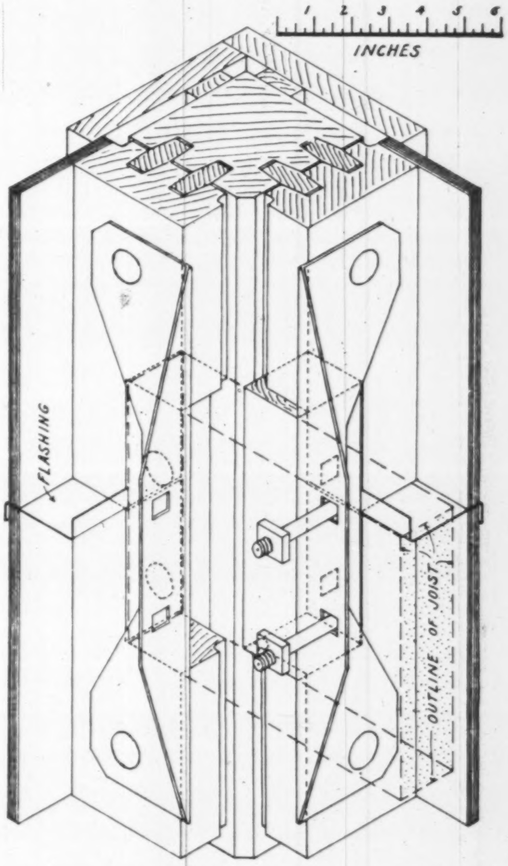


FIG. 5 CORNER JOINT BETWEEN THE FIRST AND SECOND FLOORS, INSIDE PLYWOOD AND CROSS-MEMBERS OMITTED

flashing strip is inserted to weatherproof the lower wall unit.

Sash windows, weatherstripped and spring actuated, will be used in the house. The windows and standard-size doors will require the prefabricated base and cap units shown in Figs. 3*d* and 3*e*. The interior and exterior sashes and doors will be installed on the job in the usual manner. A half-story standard stairway unit is available which is designed to be used either as a half of a continuous stair, or as a return stairway with a half-story landing.

UNIFORMITY OF EXTERNAL APPEARANCE AVOIDED

In the design of this plywood house, no attempt has been made to provide for or to standardize the roof design or the house exterior. It is frankly admitted that the roof design should vary, beyond the scope of the standardized factory production, so that in any mass-housing program there can be a clear differentiation of various dwellings which have substantially the same room content.

The use of standardized plywood units for walls and floors in no sense involves either uniform arrangement or appearance. The adoption of the 3-ft standard sections give great flexibility and means that all dimensions and house areas can be stepped up or down by the whole or half units, affording an endless variety of house plans and arrangements that will suit all sizes of families and meet serious financial limitations. Windows, doors, and ground plans can be relocated and adjusted to any frontage, land contour, or lot size. The roof and porches, added to the plywood assembly by conventional methods of house construction, may vary widely within the scope of pleasing design, and thus entirely overcome any monotonous effects that might result from unnecessarily emphasizing the standardization factors. The exterior of the house may be left in plywood, or it may be weatherboarded with standard clapboard, stuccoed, or brick veneered.

While a number of these separate units have been manufactured and tested, it has not been possible to arrive at ultimate costs comparable with the usual building estimates, no complete house having been built. Considering the qualities of stability, insulation, waterproofness, and pleasing interior, it is believed that the difference will favor the plywood type. All the machine operations are designed for reasonable production on standardized machines and the species of wood used in the plywood, which may vary from fir or gum exteriors to figured-wood interiors of mahogany or walnut, can be adjusted to the price factors involved.

The opportunity for progressive chain assembly in the factory will make the cost of the house largely dependent on volume, and with adequate volume there should be no difficulty in meeting, if not reducing, the cost of the conventional house of a grade usually erected for mass-housing programs.

A NEW METHOD OF CONSTRUCTION FOR PREFABRICATED HOUSES[11]

The units used in the method of construction described in this paper are designed so that they can be produced on a mass-production basis and erected in the field with very little labor. The units are of two kinds: (1) A plywood-panel unit made of five plies of $^1/_7$-in. veneer that can be cut into standard sizes, and (2) an I-beam made by welding back to back two sheet-steel channels cut to standard lengths. The edges of the plywood panels are grooved to receive the flanges of the I-beams. Two such panels with two of the I-beams are assembled into a box-like structure, the two panels forming its sides and the I-beams forming its edges, the ends of the box being open. Another box can be built upon the first one, one I-beam being common to both boxes. The I-beams and panels are held together by nails driven through the edges of the panels and through the flanges of the I-beams. In this way the I-beams serve as a means of fastening the panels together, edge to edge. They also serve to stiffen the edge of the panels. One of the main characteristics of this method of building houses is that the metal parts are not fastened together. In fact they do not touch each other, always stopping short of the corners of the panels. They are held in the correct relative position to each other only by the panels.

The walls, floors, and roofs of houses can be built of these box sections. The floors are made up of 9-in. I-beams with 2-in. flanges, and plywood panels 2 ft wide and of various lengths up to 10 ft. The walls are made of $4^5/_{16}$-in. I-beams with 2-in. flanges, and various lengths of plywood panels 3 ft wide. In the construction of a house, the ends of the box units will be closed with half I-beams or channels nailed in place. Heat-insulation materials will be placed inside the sections having outside exposure.

Views of the structural details of a house built up of these units are shown in

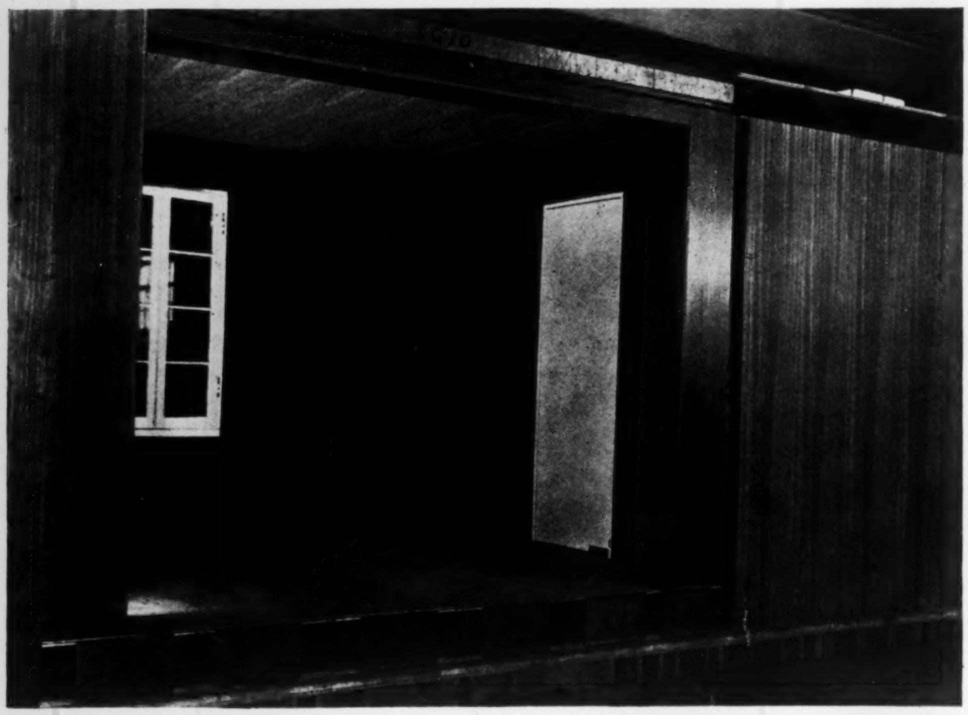


FIG. 6 DINING ALCOVE OF PLYWOOD-PANEL PREFABRICATED HOUSE

---

[11] An abstract of paper by Charles B. Norris.

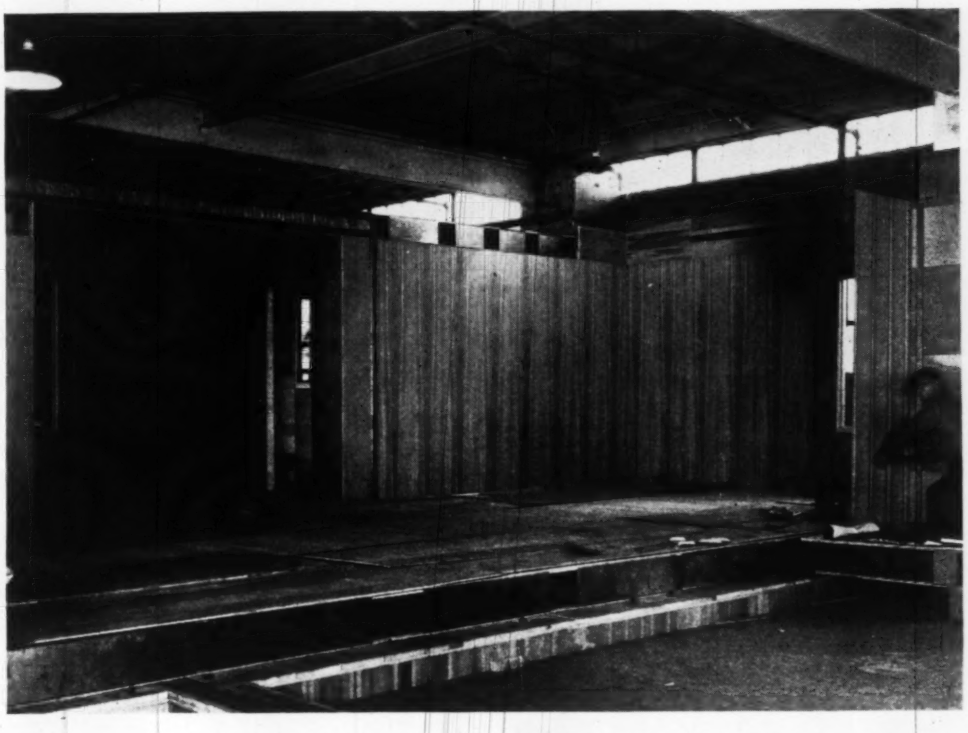


FIG. 7 THE PLYWOOD-PANEL PREFABRICATED HOUSE BEING ASSEMBLED

Figs. 6, 7, and 8. Fig. 6 shows the inside of the dining alcove and the door leading to the kitchen. The webs of the floor beams are visible at the ends of the plywood panels between the short beams marked *SA*1. The beam marked *SG*10 above the ceiling is heavier than the standard type beam and carries the end of the roof beams over the large opening between the living room and the dining alcove. The wall to the right is the inside wall of a bedroom and, as shown, it stands directly on the foundation and supports the ends of the roof beams over the kitchen.

Fig. 7 shows the house a little further along in the process of assembly. The floor of the living room and the bedroom back of the living room is complete. The dining alcove with the door opening into the kitchen is shown at the left. At the right, the walls of the bedroom are nearly completed, but the ceiling has not yet been put on. Fig. 8 shows the outside of a part of the house, the first one of its kind to be built and assembled inside of a factory building. In building the house, a mock foundation of wood was used although when constructed out of doors, a concrete foundation will be used. In this particular house the roof is flat with a parapet around it but this design is not standard. After the house here illustrated was erected, it was dismantled and reerected at other places.

Tests have been conducted to determine the strength of the plywood units. In the two floor sections 15 ft long that were tested, failure occurred at uniformly distributed loads of 5850 and 6350 lb, respectively. The action of the wall structure could not be analyzed so easily. The vertical I-beams do not extend the full length of the panels, and the roof loads are carried by the panels themselves rather than by the I-beams. In general, the inner-wall panels are expected to support the second floor and the outer-wall panels are expected to support the roof. These plywood panels are therefore subjected to edge thrust and if they were not stiffened by means of the I-beams, they would not carry a very great load. However, with such stiffening, the maximum loads run much higher than required in ordinary house construction. The results of the tests conducted to determine the strength of the floor and wall sections, show that the method of construction adopted in the building of this house is amply strong for the construction of ordinary houses. The strength of the nail fastening and the

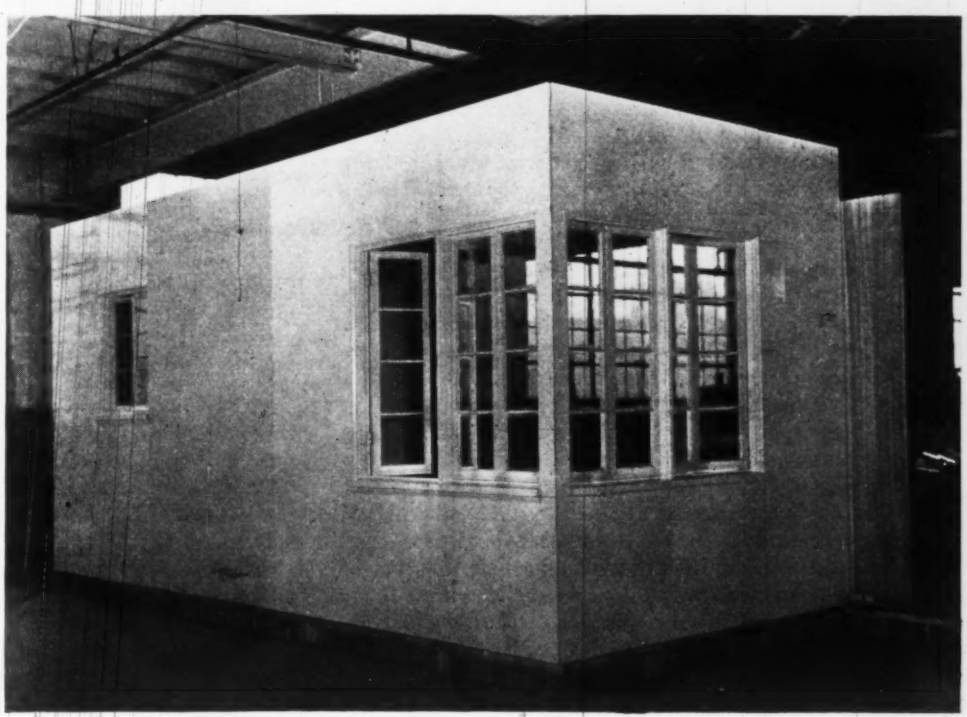


FIG. 8 EXTERIOR VIEW OF DINING ALCOVE AND KITCHEN OF PLYWOOD-PANEL HOUSE

cleavage of the panel at the bottom of the slot in its edge have been examined and found quite adequate.

In so far as the resistance of the outside of the house to weather is concerned, it can be said that the plywood panels are weatherproofed with aid of phenol-formaldehyde waterproof resins used in making plywood glues. Plywood panels made by the use of these glues have withstood weathering tests satisfactorily without protective coats of paint.

NEW DEPARTURE IN ALL-WOOD HOUSING[12]

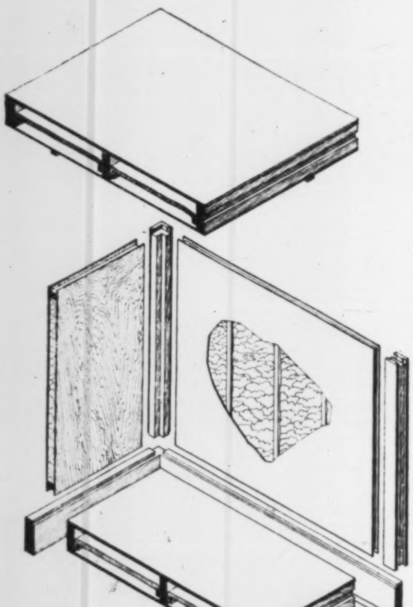


FIG. 9 A STANDARD ASSEMBLY OF PANELS WITH A CORNER MULLION. CUT-AWAY VIEW SHOWS INSULATION IN PLACE

The prefabrication system of house construction developed by the Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, that is maintained at Madison, Wis., in cooperation with the University of Wisconsin, utilizes built-up wood panels. The house built of such panels was erected solely for the purpose of studying the prefabrication system under development, and not as a commercial proposition.

One of these houses, built on a timber foundation, since it was erected for demonstration purposes only, has a living room, two bedrooms, kitchen, bath, and utility room, all in the space of 21 by 29 ft. Aside from the built-up plywood panels, 5400 fbm was used in building the structure, but all the lumber was used economically because of the system of prefabrication employed. After the prefabricated units were made, the house was completely erected in 21 hr by seven men.

The basic structural unit of the demonstration house is a built-up panel. Each panel consists of two plywood faces glued to either side of an inner structural framework to form what is virtually a box girder. The "stressed-covering" principle on which it is built, gives it the strength necessary for high-grade construction, and permits the incorporation of joists, subflooring, and ceiling into single units. Weight upon the floor is distributed through the joist to the plywood faces, so that the joists actually support only about one-fourth the load. This unity of action is due to the rigid joint formed by the glue between plywood faces and joists. In like manner, wall panels are made up of plywood, glued to studding or strips. The wall panels are 4 ft wide and 8 ft long and are made of $^{1}/_{4}$-in. 3-ply plywood glued on $^{3}/_{4}$-in. by $1^{3}/_{8}$-in. strips, which gives a total wall thickness of $1^{7}/_{8}$ in. Top and bottom members of the panel framework are set in $^{3}/_{4}$ in., and the outside vertical members are set in the same distance from the edges of the plywood faces, thus providing the structural joints necessary for assembling the panels.

Floor and roof panels are 4 ft wide, conforming to the width of regular mill plywood, while their length varies from 8 to 14 ft. Because of the strength inherent in this stressed-covering type of panel, a 2 by 6-in. structural member is substituted for the usual 2 by 10-in. joist used in conventional house construction. The upper face of the panel is made of $^{5}/_{8}$-in. plywood in five plies, while the lower face consists of $^{3}/_{8}$-in. three-ply stock.

Floor panels of this type were tested and found capable of sustaining maximum loads of 300 lb per sq ft or more over a span 13 ft 6 in. wide. Similarly, wall panels under the pressure of a gale of 60-mph developed a fiber stress in the plywood less than one-third the allowable safe stress for the material. Fig. 9 illustrates the construction of wall, floor, and roof panels.

Vertical mullions built up of three pieces glued together are used to connect wall panels, the plywood edges of adjacent panels fitting into parallel grooves of the mullions. The grooves are coated with a mastic before the panels are assembled to protect the plywood edges from moisture and to prevent air infiltration. Bottom projecting edges of the panel fit over rabbeted sill members for connecting the walls and sills, and similarly, the top edges receive a $^{3}/_{4}$-in. by $1^{3}/_{8}$-in. member glued to the roof panels along the wall and partition lines.

Lateral edges of floor and roof panels are grooved to permit a spline connection for the distribution of weight to adjacent panels. A window system with a sash larger than the opening is used; thus the window is hung outside the plane of the casing. Head jambs and sills are completely assembled on typical window panels, with hinges attached, ready to receive the sash. The closure between sash and casing is sealed with a spring-bronze weather strip while a wooden drip cap provides protection at the head.

Finished hardwood floors are laid in sections 4-ft square connected by T-shaped strips screwed to the subfloor. Gum, oak, and a special wood plastic are used for the various floors in the house.

The structure as erected included all the combinations of panels which might obtain in a large house, so that the connection problems and the necessary variations in panels could be studied in full scale. The degree to which the woodworking factory can meet close tolerances in moisture condition and machining of the wood, can satisfy exact requirements in gluing, and can insure adequate provision against long-time weathering, will determine whether the prefabricated all-wood house is to be a modern reality or just another experiment. The Forest Products Laboratory believes that all such problems can be mastered since its own machines have produced panels and mullions that fit and show no cumulative error in dimension as one part follows the other in enclosing the house.

MECHANICAL UNITS FOR HOUSES[13]

In studying the construction of houses built over a period of many years, it is observed that great advances have been made in the quality of construction materials; but it is only in the last few years that engineers have turned their efforts toward improving construction methods. It has been found after a study of costs, material, and equipment that great economy can be effected in the installation of mechanical equipment for prefabricated houses by (1) centralizing the buying power from a minimum number of organizations, and (2) centralizing and grouping the mechanical equipment of the home into a self-contained, accessible unit designed to form the central portion of the house.

---

[12] Abstract of paper by G. W. Trayer and J. S. Mathewson.

[13] An abstract of the paper by D. C. Slipher.

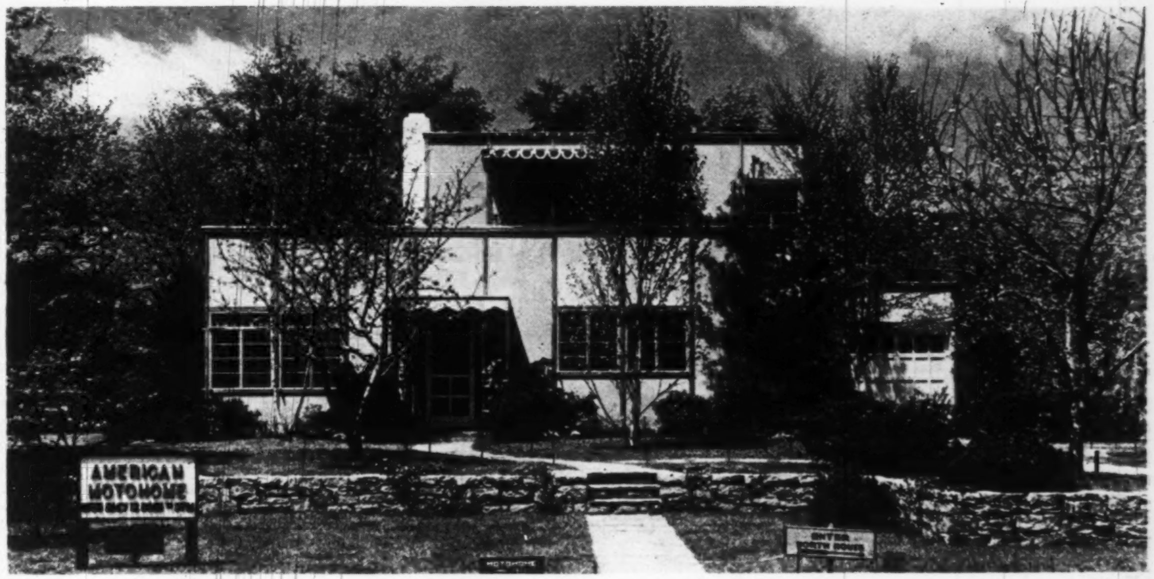


FIG. 10 PREFABRICATED HOUSE BUILT AROUND A CENTRALIZED UNIT CONTAINING ALL THE MECHANICAL EQUIPMENT FOR THE HOME

These features have been incorporated in the prefabricated house shown in Fig. 10. The house is set on a concrete foundation to which are bolted 16-in. steel beams. The house needs no cellar since all the mechanical units for the home are contained in the central compartment of the house. The first floor is kept dry and warm because beneath it there is an enclosed chamber 16 in. deep, which extends under the entire floor area and through which warm air is circulated. A steel frame, anchored to the concrete foundation and designed to withstand heavy snow loads and high wind velocities, supports 16-in. beams for the second floor and the roof.

The exterior walls are made in large panels which are fastened to the steel wall frame. These panels are made of cement and asbestos compressed under hydraulic pressure with integral insulation. The exterior trim is of special aluminum alloy which weathers to a mellow pewter color. The roof material is made of a mineral compound 2 in. thick, reinforced with steel, and secured on the top of the 16-in. roof beams. The flooring in the house is made of the same material as is used in the roof, although the finished floors are made of hard wood, the fibers of which have been exploded under great pressure and then compressed into thin sheets. The interior walls, made in large sections from a mineral compound and held in place by steel channels, are soundproof and are covered with a washable material. Steel casement windows which operate by means of a crank and which lock automatically, are used throughout the house.

The feature of the house is the centralized mechanical unit made in four sections: (1) A kitchen section, (2) a heating and air-conditioning section, (3) a bathroom section, and (4) a laundry section, although the latter section is not included in the smaller models of the homes. All the plumbing, heating, air-conditioning, and all the electrical and mechanical devices for the entire house comes to the building site complete in a large metal cabinet comprising this unit. The house is built around the cabinet containing the unit, one side of the cabinet becoming the kitchen and the other side the bathroom. In two-story houses, this mechanical core extends up through the ceiling to provide either one or two baths on the second floor.

In the kitchen section, the electric refrigerator, sink, laundry tub, and stove are arranged compactly in a continuous straight line as shown in Fig. 11. These are all contained in an enameled insulated-steel cabinet covered by a continuous flush metal work-top. Adjoining the kitchen unit is the heating unit comprising a domestic hot-water tank, heater, and air-conditioning unit. The bathroom unit, is an enameled-steel insulated cabinet to which the various bathroom accessories are attached, the accessories being specially designed for this particular type of installation. The laundry units include an electric washing machine, a laundry tub, and enameled storage cabinets.

A number of these prefabricated homes have been built. They provide a material economy in the centralizing of the mechanical equipment, and in erection, which can be completed in two or three weeks, depending on the size of the structure.

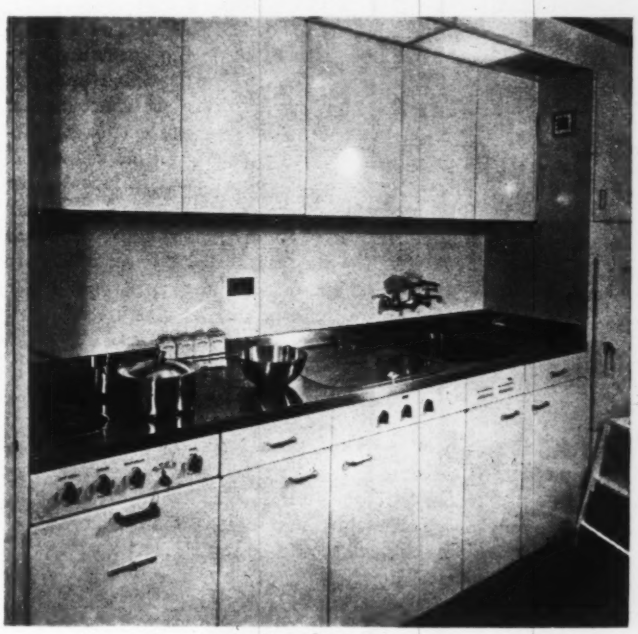


FIG. 11 KITCHEN OF CENTRALIZED SERVICE UNIT AROUND WHICH HOUSE SHOWN IN FIG. 10 IS BUILT

The PASSAMAQUODDY TIDAL-POWER PROJECT[1]

THE Passamaquoddy (Quoddy) project is located in the vicinity of Eastport, Maine, entirely in American waters but in close proximity to the Canadian border.

GENERAL DESCRIPTION OF PROJECT

This project will provide for the generation of power by creating and maintaining a low-level pool about 37 sq miles in area in Cobscook Bay, Maine, by the construction of a series of dams, a power house, and an emptying-gate structure between Cobscook Bay and the Bay of Fundy. It is planned that the interior basin shall be maintained at or near low-tide levels. As the tide rises and the difference in head between the sea and the basin exceeds 5 ft, the power house will be opened and power generated from the rising tide. The mean range of tide at this locality is approximately 18 ft. Generation of power is continued during the falling tide until the difference in head between the sea and the interior basin, which by now has risen about 2 to $2^{1}/_{2}$ ft, again reaches 5 ft, when the power house is shut down. When the elevation of the sea reaches that of the basin, the emptying gates are opened and the interior basin drained to approximately low-tide level.

In the absence of an auxiliary means of generation of power, this arrangement would provide no primary power, due to the necessity of shutting down the power house during the lower tide levels for 5-hour intervals twice a day. Provision for primary power development is made by a pumped-storage plant near Haycock Harbor about 15 miles distant. Surplus peak power generated at the main tidal power plant at and near high-tide levels is transmitted to a large pumping plant located on the sea near Haycock which pumps water into a large reservoir 125 to 135 ft above sea level. During the shut-down periods of the main tidal power plant, this stored water is used to generate power at the Haycock power plant.

The initial development will be so constructed as to be readily adapted to a much larger two-basin development utilizing both Passamaquoddy and Cobscook Bays, which may be provided when increased power demands warrant further development. The expansion will be international in character, as the second basin lies almost entirely in Canadian waters. In the ultimate development the upper basin, about 100 sq miles in area, would be cut off from the sea by a series of dams, locks, and a gate structure generally similar to those proposed for the initial development. Whereas the Cobscook Bay basin now being constructed is to be maintained at as near low-tide level as possible, the upper basin would be maintained at or near high-tide level, so that the maximum difference in head between both basins would be provided for power development. The upper basin would be provided with a filling-gate structure which would be opened at and near high tide, in order to fill the upper basin to approximately high-tide levels. Power would be generated through the same power house now being constructed as part of the initial development, it being necessary only to install additional units. The great advantage would be that the head would be more nearly constant instead of fluctuating directly with the tide so that a fairly steady source of primary power would be provided.

DETAILED DESCRIPTION OF PROJECT

The initial development will embrace a series of earth-fill rock-armored dams and rock-fill dams, the main tidal power house, the emptying-gate structure, and the lock. The dams will range from 30 to 150 ft in height and up to nearly 4000 ft in length. The power house will be built to provide for 22 units, only 10 of which will be installed initially. The units tentatively proposed are to be of 16,667 kva capacity at from 40 to 45 rpm, and designed for heads varying from 5 to 25 ft. The emptying-gate structure will consist of a battery of massive vertical-lift gates in venturi-type sluices designed to discharge a maximum capacity of 550,000 cfs, in order to draw down the lower basin to low-tide level in a minimum time under a small difference in head. A navigation lock is to be provided to permit navigation to have access through the dams into the interior basin and its tributary area.

The pumped-storage development at Haycock Harbor will consist of a large pumping installation of 180,000 hp capacity, and a power plant of 44,800 kw capacity, together with the necessary dams and levees to create a reservoir at elevation 120 to 130 ft for pumped storage. An integral part of this development will be a transmission line extending 16 miles to its connection with the main tidal-power plant to be designed for 150,000 kva capacity at 66,000 volts.

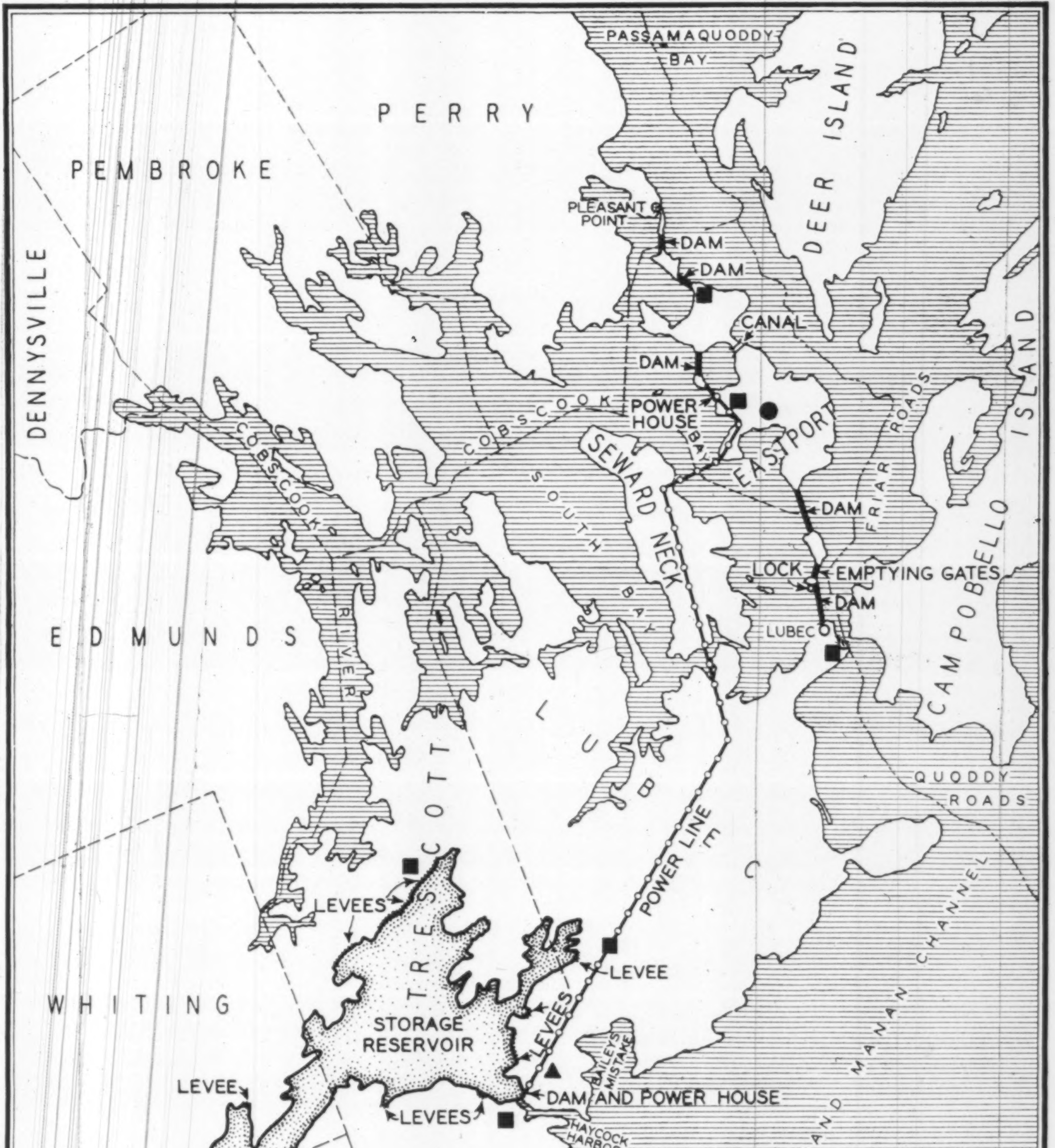
This project will afford much unemployment relief to skilled, semi-skilled, and unskilled labor, as well as to technical and clerical personnel in the State of Maine. According to recent FERA figures 41,000 employables are currently on relief rolls in Maine, including 7000 in Aroostock County and 2200 in Washington County where the project is located.

WHILE much has been written about tidal-power projects, the world has seen few of them except the mills of relatively small capacity that have been built in England, on the Continent, and in New England. The project described in the foregoing article is located in a region where there is an unusually large difference in water level at high and low tide and recalls proposals made some time ago by D. S. Cooper for a two-basin scheme at this same site, described by him in the Transactions of the Connecticut Society of Civil Engineers, 1926. In the closely adjacent Bay of Fundy, near Hopewell, N. B., a tidal project was proposed about 15 years ago and was described in the *Journal* of the Engineering Institute of Canada for October, 1919, pp. 647–658.

The intermittent movement of tides has driven designers to plan two- and three-basin schemes in order to obtain continuous operation, and to storage devices so that power may be generated intermittently but used whenever needed. The pumped-storage scheme at Passamaquoddy is one such device. Energy storage in compressed air and in heat have also been suggested. A. M. A. Struben, in 1921, wrote a helpful little book entitled "Tidal Power," published by Sir Isaac Pitman & Sons, Ltd., that covers briefly tides and their measurement, the estimation of potential tidal power, comparisons between systems of development, the financial aspect of the problem, the difficulties to be overcome, and the lines for development.—EDITOR.

---

[1] MECHANICAL ENGINEERING is indebted to Capt. Hugh J. Casey, Corps of Engineers, United States Engineer Office, Eastport, Maine, for this statement.


PASSAMAQUODDY BAY
DEER ISLAND
PERRY
PEMBROKE
DENNYSVILLE
PLEASANT POINT
DAM
DAM
CANAL
DAM
POWER HOUSE
COBSCOOK
COBSCOOK BAY
EASTPORT
SEWARD NECK
SOUTH BAY
COBSCOOK RIVER
DAM
FRIAR ROADS
CAMPOBELLO ISLAND
LOCK
EMPTYING GATES
DAM
LUBEC
EDMUNDS
TRESCOTT
LUBEC
QUODDY ROADS
POWER LINE
LEVEES
LEVEE
STORAGE RESERVOIR
LEVEES
WHITING
LEVEE
LEVEES
DAM AND POWER HOUSE
BAILEYS MISTAKE
HAYCOCK HARBOR
MOOSE R.
GRAND MANAN CHANNEL
● DISTRICT OFFICE
▲ AREA OFFICE
■ CONTRACTORS' CAMPS
LEVEE
CUTLER

MAP OF PASSAMAQUODDY DISTRICT, SHOWING LOCATION OF DAMS, POWER HOUSE, EMPTYING GATES, AT EASTPORT, MAINE, PUMPED-STORAGE RESERVOIR, WITH ITS LEVEES, DAM, AND POWER HOUSE, AT HAYCOCK HARBOR, AND INTERCONNECTING POWER LINE

INTERNAL DEBT *and* LIQUID CLAIMS *to* WEALTH

By OLIN INGRAHAM

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

WHILE Clark's book[1] is two years old, it is worth while reconsidering and coupling with the later book,[2] for without it "Liquid Claims and National Wealth" might not have been written; certainly would not have found as large a number of prepared readers. For Clark, in showing the enormous increase of debts from 1914 to 1929, convinced many of us that that was a central reason for the depth, and especially the length, of the present depression. During the depression Hoover said that we could not borrow ourselves into prosperity. Before the depression that was precisely what we had done, but it made a dangerous prosperity.

The first two-thirds of the volume is taken up with estimates of the different classes of long-time debts. It is the same story for all classes except farm debts, which became stationary after 1920, and the national government debt, which was rapidly reduced. For all other classes it was an expansion beyond any justification in the change of the purchasing power of the dollar or in the increase of total wealth or income.

Side by side with the increase of long-time debts of states and smaller political units which totaled $4,721,000,000 in 1914 and $16,556,000,000 in 1929, went the increase of industrial debts from $3,738,000,000 to $10,170,000,000, the increase of public utility debts from $3,294,000,000 to $9,469,000,000; greatest of all, the increase of urban mortgages from $5,151,000,000 before the War to $27,616,000,000 in 1929. The total of long-time debts, Clark estimates, increased from $37,989,000,000 to $126,443,000,000. Great was the increase during this time in wealth and income measured in dollars, but Clark estimates that the per cent of debt to total wealth rose from 19.7 to 32.7, the per cent of interest charges to total income from 6 to 9. Then came the depression and 1932. In that year Clark estimates that the per cent of long-time debts to total wealth had risen to 44.7; the per cent of interest charges to total income to 19.8.

The last third of the volume is devoted to the more uncertain estimates of the total of short-time debts. Clark gives as "very rough guesses" an increase of the total of short-time debts from $51,000,000,000 at the end of 1913 to $150,000,000,000 in 1929. Then follows a chapter on "General Recommendations," dealing mainly with the present emergency, dealing but slightly with the problem of protecting ourselves from a similar emergency in the future.

Clark's book, therefore, is chiefly an analysis and summary of quantities. The mighty quantities can speak for themselves. In Berle and Pederson's "Liquid Claims and National Wealth" there is indeed a quantitative summary with much the same result of showing the great increase in the percentage of liquid claims to national wealth in recent times. But in the first place, only liquid claims are totaled; in the second place, claims other than debt, the market value of stocks, form a part of the total. So defined, the percentage of liquid claims to national wealth was 16 in 1880 and had risen only to 20 in 1912. But by 1930 it was 40. Then, as stocks were included, the percentage falls slightly and in 1933 was estimated at 34.

So much for the quantities. But a large part of the book is taken up with discussion of this or that phase of liquidity. There is a chapter on the evolution of liquidity in the law. In dealing with the economics of liquidity the authors emphasize the difference between the liquidity involved in the movement of goods, the "self-liquidating debts," so called, and the liquidity of the sales of securities and the loans based on securities. The authors call the first "real" liquidity and the second "artificial," and that shows their bias. For I think it is evident after the experience of the drastic depression of 1920–1922 and our present slower, longer depression that loans on goods are only self-liquidating in the milder depressions, that in the severer depressions either the goods will not sell or the price must be cut till eventually it becomes below the amount borrowed per unit. Neither extreme, the controlled price under which sales dwindle, nor the free market in which prices fall, provides an amount of payment under which debts can be liquidated and borrowers continue in business.

But we are moving into a condition in which this system of "real" liquidity plays a smaller and smaller proportionate part in our economic life. The earning assets of commercial banks which once were mainly loans on the movements of goods, are now two-thirds investments and loans on securities. Wall Street, which used to be a local street, now spreads over the whole of the United States. We have built up this mighty system of what the authors call "artificial" liquidity.

The authors contrast the two types of liquidity: "The conclusion seems warranted that liquidity turns ultimately on flow. The flow of goods toward a market which presupposes an outflow of consumption and an inflow of production more or less in balance. And a second flow, the flow of savings toward investment in capital. . . . These two flows plainly have an entirely different tempo." Surely, however, "artificial" liquidity is mainly a matter of a resale market. It is the liquidity of an ocean not of a stream. Surely, also, so far as it is a matter of new savings seeking new investments, the fluctuations of the stream of saving-investments and the fluctuations of the stream of physical products are much the same thing. The net reduction of locomotives and the minus saving of locomotive companies run pretty much parallel to each other during this depression.

But is the liquidity of securities "artificial?" I think not. I think it fits our present American economic life like a glove. We are living in a world in which the proportion of employees and professional people becomes larger and larger to the total, therefore a larger and larger proportion of us cannot put our savings in our own business. Nor can we put our savings in our homes without running the risk of affecting the geographical liquidity of our jobs. It is an interesting revelation of the census that decade by decade a larger and larger proportion of people live in some state other than the one in which they were born. America is on the move as it never was when it had a frontier.

---

[1] "The Internal Debt of the United States," by Evans Clark. The Macmillan Co., New York. 1933, $4.50.

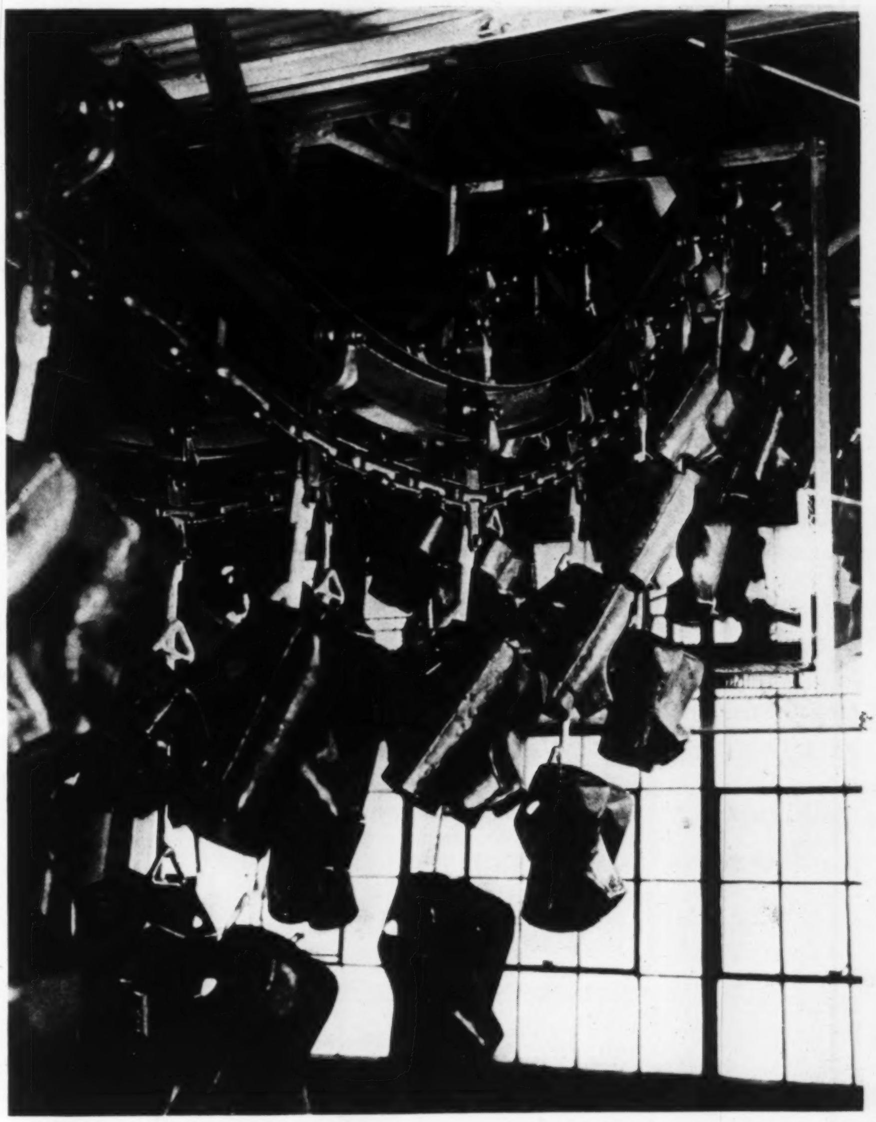
[2] "Liquid Claims and National Wealth," by A. A. Berle, Jr., and V. P. Pederson. The Macmillan Co., New York, 1934, $2.50.

Sixth of a series of reviews of current economics literature affecting engineering prepared by members of the Department of Economics, Massachusetts Institute of Technology, at the request and under the sponsorship of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

So savings must be in something that can be resold. The individual can use the great financial middleman like banks and insurance companies for the direct object of his savings. And the twentieth century has seen the assets of mutual savings banks increase fourfold and of life-insurance companies tenfold. Such investment seems the part of individual prudence, but as, in turn, the savings banks and life insurance companies must invest in debts, it really provides the lender's condition for the dangerous expansion of debts which we have discussed in reviewing the book by Clark. Obviously, also, our rapid expansion of debts is likely to mean an expanding proportion of debts against total assets, a dwindling proportion of equities. Such dwindling proportion will then go through a much larger percentage of market-price oscillation between prosperity and depression. The old New England railroads used to be financed by common stocks. Suppose our railroads now had no bonds—few of them would have been in the red. The yield per share of common stock would have fluctuated but mildly. Conservative savers have therefore made Wall Street dangerous. Of course I do not limit the dangerous people to savers.

For the other alternative, an inexperienced horde directly investing in Wall Street has shown its results spectacularly enough in the last ten years. Is there anything that can be done about it? We can all imagine a series of modifications which could have palliating effects. But in any case we would hesitate to turn back the clock and hand out non-liquid investments in the place of liquid. Suppose the clock goes on and, as the authors suggest, all investments become liquid. The authors fear that a depression would create an impossible selling market, but we might, on the other hand, imagine that we would then have a market in which every one could realize at a price, that nothing could be unsalable, and therefore nothing would have to be sacrificed.

Of course, I have been unable here to take up the many fertile suggestions included in this book. It is, as the authors state, "an exploratory essay."



CONVEYER LINES AT THE DETROIT PLANT OF THE CHEVROLET MOTOR COMPANY

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The Hornet Moth

THIS machine is intended to take the place of the open-cockpit biplane known as the Moth, and is a cabin biplane powered with a Gypsy Major 130-hp 4-cylinder inverted in-line air-cooled engine. It is of the tapered-wing type of biplane with a waterproof fuselage of monocoque construction and is fitted with wheel brakes with a full caster-action tail wheel; the fairing of the chassis legs can be turned in flight to present their broadside elevation to the air stream and the effect is a powerful air brake. The elevators incorporate a new system of adjustable tab which is controlled by the pilot to adjust the fore and aft trim under all conditions of loading and engine thrust effect. It is said that the plane is unusually easy to fly and that a pilot can cruise indefinitely, execute all maneuvers, and even land without touching the rudder bar, which may be used only for directional control when taking off and for ground maneuverability. Provided the rudder is not used, it is almost impossible to make the Hornet Moth spin. The overall length of the plane is 24 ft $9^{1}/_{2}$ in. and the span with wings open is 32 ft $7^{1}/_{2}$ in., and with wings folded 9 ft 6 in.; the overall height, tail down, wings folded, is 6 ft 6 in., and it is stated in this connection that with the wings folded it can be housed in a garage little larger than one for a standard motor car. (Abstracted from a communication to this Society from the de Havilland Aircraft Co., Ltd., Herts, England)

APPLIED MECHANICS

Estimating the Ultimate Strength of Materials

THE author believes that the method of determining the ultimate strength in tension is sufficiently perfect to give reliable data for the designer's use. The result of experiments relating to other stresses, such as shear and torsion, must be utilized with caution, and the author cites several examples showing the occasionally great deviation of estimated strength data from those determined experimentally. One such example deals with torsional-strength tests on a silico-manganese steel with a chemical composition approaching S.A.E. steel No. 9260. Experiments were made with specimens of different weights and sizes in condition as received and after quenching in an oil bath. It was found that the fundamental torsion formula for a rectangular section could not be applied to short specimens made of square or flat steel and a strength-correction factor should be introduced. Such a factor is given in the original article.

The next subject analyzed is the bursting strength of pipes. Here it was found that the length of the specimens is a particularly important factor when testing short pieces, and that the material of 2-in. welded pipes weakened by welding and subjected to compound stress under cross and longitudinally acting forces is really stronger than the material of the same class subjected to simple tension. The material of seamless steel pipes has proved to be two to four times stronger than the material of the same class subjected to tension, and the ratio of the bursting strength to the ultimate tensile strength of material used diminishes with an increase of the length ratio.

The author gives a formula for calculating the resistance of the tube walls to deflection or any circumferential elongation of its material. He next calculates the bursting pressure for a 5-in. seamless steel pipe 25 in. long, a working pressure of 900 lb per sq in., wall thickness 0.375 in., and outside diameter 5.56 in. The bursting pressure according to the author's formula is 13,500 lb per sq in. against 10,000 lb per sq in. estimated from the fundamental formula for bursting strength of pipes subjected to internal pressure. (Victor Tatarinoff in *Heat Treating and Forging*, vol. 21, no. 4, April, 1935, pp. 185–187, 4 figs.)

ENGINEERING MATERIALS

Tests on Cast Iron as a Bearing Metal

COMPARATIVELY little is known about the experimental work carried out in Germany during the War with the aim of replacing scarce, chiefly foreign, materials by domestic materials. The problem facing German engineers today is to create a bearing material which would be as free as possible of tin, as well as other materials either not easily available nor excessively costly. Among others, the H. Lanz Co., of Mannheim, sought to solve this problem in connection with the manufacture of agricultural machinery. After a series of thorough tests with brass, bronze, various kinds of cast-iron, aluminum alloys, and artificial resins, it was found that high-grade cast-iron bearings promise the best results.

There was a time when cast iron was extensively used as a bearing material but as a result of constantly growing stresses and velocities, the bearings were asked to do more and more. Cast iron of that time was a material lacking in regularity and reliability, as a result of which combination of circumstances it gradually lost a good deal of its standing as a bearing material. In the last twenty years, however, it has been improved to an extraordinary extent. Its physical-strength characteristics have been increased about 100 per cent in that short period of time, in addition to which the reliability and uniformity of its production have been likewise improved to an extraordinary degree. Notwithstanding the competition of light alloys and welded steel, high-grade gray iron has recovered several of its previous losses. The question now is, "What about its wear?"

EARLIER TESTS ON WEAR

The author mentions a number of investigations dealing with wear and sliding friction of various materials, but states that there is as yet no complete agreement as to what wear is. Some investigators take it as meaning fragmentation and displacement of the crystalline structure of the surface which finally reaches the point where certain groups or parts of crystals form local projections and lead to destruction of the surface. Others take wear to mean thermal and chemical processes and consider the subject in connection with the decomposition of lubricating oils pro duced by the heat effects, as well as frictional oxidation, on the most highly stressed sections of shafts and bearings. The wear occurs only when the oxidized parts have been generated and then removed.

Special machinery has been designed in order to solve the problem of wear when metal works against metal. The author describes and illustrates his own experimental apparatus. It was found that wear depends only in part on the material of the bearing and is further affected by the following: (1) Construction clearances and mountings of the bearings; (2) character of the surface of the sliding surfaces; (3) lubrication of the bearing; (4) protection against dust; (5) velocity of sliding and duration of running; (6) pressure on the surfaces and temperature at the points of sliding.

While these factors are generally more or less known to practical engineers their importance has been undervalued in the majority of cases. In the case of any bearing it is above all necessary to bear in mind that the specific bearing pressure selected should not be exceeded at any place, which means, for example, that there should be no edge pressures due to improper mounting, rigid construction, or bending of the shaft. This means that the bearing construction should be elastic and not rigid.

The matter of bearing clearance is of particular importance. If it is excessively small, dry friction and seizing may easily take place; if it is too large (which is less dangerous than otherwise) hard knocks will occur in the bearing. If the bearings are carelessly mounted, trouble from overheating may occur because of the presence of dirt and edge pressures.

The author discusses next the influence of the other factors enumerated. This part will not be abstracted, because of lack of space. He then states that once these six basic requirements have been satisfied the question of selecting the proper material for the bearing may be tackled.

Theoretically, in each sliding bearing fluid friction occurs, which means that between the shaft and the journal there is a film of fat or oil adhering to both. The part of the bearing metal is determined by its affinity for the material of lubrication. The ability of the bearing to resist displacement or rupture is determined by the layer of lubricant which varies with the structure of the molecule of the lubricant. Under certain unfavorable conditions one must be prepared to encounter trouble. This may occur, for example, in the case of pitch formation in the bearing after the machine has been standing idle for a long time. In such cases one should not start under full load. If dry friction occurs the ability of the metals to wear against each other comes into play. In such a case the majority of white metals or copper alloys have unquestionably greater advantages in that their failure does not hurt the shaft. When cast iron is used there is the danger that if the bearing begins to run hot, the temperature may rise to such a point that martensitic hardening will be produced. This matter was covered in the tests described in this article.

Tests were made with a shaft 40 mm in diameter and journals with tolerances from +0.025 to +0.085, both ground and polished.

Apart from preliminary tests all the work was carried out with a sliding velocity of 1.69 m per sec. As a lubricant Shell medium oil was used, 10 to 11 deg Engler at 50 C.

All the comparisons were made with journals manufactured of casting bronze GBz 14 standard number, finely machined. The test did not show properties of any particular excellence, and notwithstanding the fact that the six requirements enumerated were carefully considered, it was found that the limit of seizure was at a load of from 26 to 70 kg per sq cm. No tests were made with bronzes containing tin, as this was excluded for commercial reasons. In the case of cast iron the finish was exclusively by grinding and polishing, which, together with the price difference between the cast bronze and the cast iron used (standard number Ge 26.91) would be in the latter's favor. Another cast iron Ge 18.91 was tried but found unsatisfactory. On the other hand, fifty journals of various kinds of polish made of Ge 26.91 (Lanz pearlite) did not show a single case of seizure as long as the bearing load remained below 50 kg per sq cm. The individual values are given in a graph in the original article. The maximum pressures previous to seizure were as high as 250 kg per sq cm, and a figure in the original article gives graphs showing the degree of safety against seizure of the bronze tested and cast iron Ge 26.91. Previous investigators have indicated a material increase in resistance to wear of cast iron due to higher content of phosphorus. The present tests have shown this to a much smaller degree. This could be explained by the circumstance that in earlier types of cast iron there was a considerable amount of ferrite present and the bearing properties of the ferritic iron showed more improvement through formation of phosphide than purely pearlitic iron.

GENERAL RESULTS

Among other things it has been shown under what conditions the casting bronze GBz can be replaced by a product manufactured out of raw materials native to Germany without increasing the cost of production. The material in question is cast iron Ge 26.91. It was found that the new material can carry loads approximately twice as great as former materials and that for the same size of bearing the danger of wear was materially reduced and protection against dust increased. With the same factor of safety much smaller bearings will be used in future. In one type of agricultural machinery up to 60 per cent of the bearings formerly made of GBz bronze was replaced by pearlite cast iron without producing any undesirable results.

The problem next to be investigated is to find out why seizure at low loads takes place. It is also desirable to carry out tests with various shaft diameters from 25 to 60 mm as well as to make tests with aluminum alloys and synthetic resins. (W. Meboldt, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 21, May 25, 1935, pp. 629–631, 4 figs.)

Low-Melting-Point Alloys

WOOD and Lipowitz alloys, although characterized by low melting points, have not proved entirely satisfactory in practice. A series of new low-melting-point alloys have been developed by the Cerro de Pasco Copper Corporation.

The Cerro-matrix alloy has been used in the production of molds for the pressing of wood composition and fiber in order to reproduce wood carvings. Its comparatively low melting temperature allows it to be cast directly against the wood carving without danger of charring the wood. The alloy is also used for making forming blocks used for dressing automobile metal panels and components by hammering into various complex shapes. This may be used for removing dents from damaged automobile parts.

The Cerrobase alloy is used for making foundry patterns, when the pattern is duplicated in order to have enough of them to facilitate production. Cerrobase alloy is also used for safety plugs in boilers. It is important that such plugs should be replaced with new ones at least once a year, as the melting point tends to rise under continued heat.

Cerrobend or Bendalloy is extensively

used in motor-car and aircraft factories to reinforce copper, brass, and duralumin thin-walled tubes on the inside during the bending of shapes and to prevent crimping and buckling. It is also used in the forming of spouts for domestic kettles and in the production of hollow silverware.

Cerrobend is also being used satisfactorily for master patterns in pantographic and engraving machines. The molten alloy is poured at approximately 100 C on to a wooden pattern previously prepared. The alloy takes a considerable time to cool, and during this period it is slowly stirred. This stirring avoids the formation of blowholes in the castings. The wooden pattern is removed and the Cerrobend model is then ready for use on the machine without further treatment. These master patterns in Cerrobend do not crumble by continual pressure of the chaser, and are always available when required for repetition work.

Cerroseal is a fusible bismuth alloy for making air, oil, and water-tight connections between metal and glass or porcelain. The alloy actually "wets" the glass, but the metal should be previously tinned.

The alloys mentioned are especially suitable for gravity die-casting work where the metal must flow easily and fine and detailed impressions are required.

It is not generally known that the incorporation of 10 per cent bismuth in aluminum solder has been found beneficial and that lead containing up to 10 per cent bismuth can be easily rolled into tape form, which has been found particularly useful for electrical purposes. (A. Eyles, *Machinery* (London), vol. 46, no. 1183, June 13, 1935, pp. 323–324)

FUELS AND FIRING

Cyclopentadiene Coal Byproducts

USING cyclopentadiene, a product known since 1886 as an intermediary, the Bethune Co. succeeded in developing a new line of pharmaceutical products and perfumes. Cyclopentadiene has been extracted by distillation of coke-oven tars. At Bethune it is carried with the hot raw gases coming out from coke ovens. It is present in extremely small quantities of the order of a few fractions of a gram per cubic meter of the gas. These gases at the Bethune Co. were treated by fractionating liquefaction primarily in order to separate out the hydrogen later used for the manufacture of synthetic ammonia. Since the process was available, however, it was applied to the separation of the other constitutents of the gases. The process proved to be economical and produced as a final result solid crystallized dicyclopentadiene. The total output of cyclopentadiene is from 15 to 20 kg out of 300,000 cu m of gas which corresponds to coking of 1000 tons of coal. The pharmaceutical products obtained are chiefly of the class of barbituric acid and its derivatives. The perfumes are of the class of cyclopentenyl-alcoylaceticesters. Some other products, such as lactones of the same acids, also have been obtained. (R. Horclois in a report of the 13th Congress of Industrial Chemistry, Lille, France, September, 1933, published as a special number of *Chimie et Industrie*, April, 1934, pp. 357–363)

MACHINE PARTS

Hollow Set and Socket-Head Screws

MANY of the possible advantages obtainable with these screws are reflected in the design of the parts where the screws are used. By virtue of their greater strength and holding power, these screws can be used without locking devices on internal as well as external mechanisms. By elimination of projecting screw heads, danger to operators is overcome and flush surfaces are obtained. Because these screws are made of alloy steels and are heat treated they are much stronger than those made of ordinary screw stock. Therefore, smaller sizes can be used than would be possible with untreated carbon-steel screws.

This is illustrated in a table of screw sizes. The figures given in this table apply to both coarse- and fine-threaded screws. It is not unusual for heat-treated alloy-steel hollow set and socket-head screws to withstand a tensile stress of 250,000 lb per sq in. This is especially true for setscrews where less ductility is possible, because stresses are compressive rather than tensile as in capscrews.

One of the advantages of socket-head capscrews is that they permit more compact design. The indentation is smaller and neater when using a socket-head capscrew in preference to a hex-head capscrew.

When a screw is to be placed in a walled corner, the deciding factor controlling the proximity of the screw to the corner is the wrench, or the diameter of the socket when a socket wrench is used for tightening. Because of the smaller screw-head size and the type of wrench used, the head of the socket-head screw need only to clear the wall, making possible a narrower flange and a tighter joint.

Hollow or socket-head screws are not limited to one or two diameters as on setscrews or fillister-head screws. Head-shoulder screws having three diameters, obtainable in numerous body lengths, are used as bearing studs for links, levers, gears, cam attachments, and other parts as illustrated by the two methods in Fig. 1. Three-diameter socket-head screws are also used in punch and die work as stripper bolts for spring guidance. Tiny slotted setscrews are difficult to assemble, especially in close quarters. Using a fluted wrench having four driving surfaces, No. 5 screws (0.125 diam.), which are the smallest made, can be placed on the end of the wrench and assembled with ease. The screw cannot slip off the wrench end as a slotted screw would, a highly important advantage especially in these smaller sizes. (*Product Engineering*, vol. 6, no. 4, April, 1935, pp. 130–132, 9 figs.)

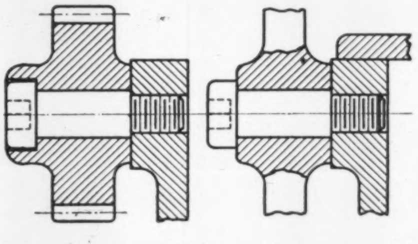


FIG. 1 CROSS-SECTIONS SHOWING HOW STANDARD SOCKET-HEAD SHOULDER SCREWS MAY BE USED IN PLACE OF SPECIAL STUDS OF MOUNTING GEARS, LEVERS, LINKS, AND OTHER ATTACHMENTS

MOTOR-CAR ENGINEERING

Low-Cost Oxygen

MORE than ten years ago the U. S. Bureau of Mines issued a report on the use of oxygen or oxygenated air in metallurgical and allied processes (Report of Investigations Serial 2502). In this report it was pointed out that it was the lack of proper manufacturing and distributing organization that caused the high prices for oxygen. Since then improvements in the art of air liquefaction and rectification made possible a radical reduction in the initial air compression required which meant less power, and power is the major cost factor in oxygen production. This and other factors created a situation where today it is possible to manufacture gaseous oxygen at an operating cost of \$3.50 per ton with power at $^1/_2$ cent per kwhr and at \$5 per ton with power at $^3/_4$ cents per kwhr when producing 150 tons daily from three 50-ton units. The present article deals exclusively with the application of oxygenated air to metallurgical purposes.

To illustrate the furnace temperature increase effected by the use of oxygen enrichment of the hot-air supply in the open-hearth furnace, a table in the original article shows the comparative values of different fuels, based on 5,000,000 Btu input to the furnace.

In the open-hearth furnace 44,600 cu ft of blast-furnace gas preheated to 1100 F, plus 6700 cu ft 95 per cent oxygen will generate 5,000,000 Btu with a flame temperature of 4185 F.

Open-hearth furnaces can be maintained at operating temperatures with preheated blast-furnace gas and oxygen, thus providing a new use for blast-furnace gas. This is especially desirable when operating blast furnaces with enriched cold blast, thereby eliminating the hot-blast stoves, so that this excess blast-furnace gas is available for open-hearth operations. (Theodore Nagel, V.-P. and Ch. Engr., Carbureted Gas, Inc., in *Mining and Metallurgy*, vol. 16, no. 341, May, 1935, pp. 215–216)

POWER-PLANT ENGINEERING

Equalization of Power and Heat by Steam Compression

THE long-distance heating system of Braunschweig, Germany, consists of two turbines, each of 4200 kw capacity, and one turbine of 10,000 kw capacity, all of them supplied with bleeder steam. No provision is made for the regulation of the pressure of the extraction steam; and the extraction for the 4200-kw turbines is from the first stage and for the 10,000-kw turbine from the fourth stage. As shown in Fig. 2, the extraction pressure depends to a large extent on the load on the turbine existing at any particular time. As long as the initial pressure in the heating system is lower than the extraction pressure at the turbines, the amount of steam can be controlled by means of throttle regulation of the extraction valve. This initial pressure depends, however, on the amount of heat taken by the heating system and the existing demand for heating. Line *a* in Fig. 3 shows the steam pressure that has to be maintained ahead of the entrance to the city system. Line *b* shows the required pressure at the distributer of the power plant located at a distance of some 1600 m, as a function of the throughput of the steam and the external temperature (demand for heating).

The article shows that on a winter's day the peaks of the output produced and the demand for heat do not coincide; the former, at an outside temperature of —14 C, attains its maximum value at 9 o'clock, when the morning peak of steam consumption has already begun to fall off. Contrariwise the steam consumption of the heating plant has already decreased materially by the time the evening lighting peak load comes on, with the result that from 6 p.m. on, the high extraction pressure available cannot be utilized. If the pressure desired for the heating plant is not available or just barely available at the bleeder connection of the turbine, extraction becomes impossible and the heating plant has to be run on throttled live steam.

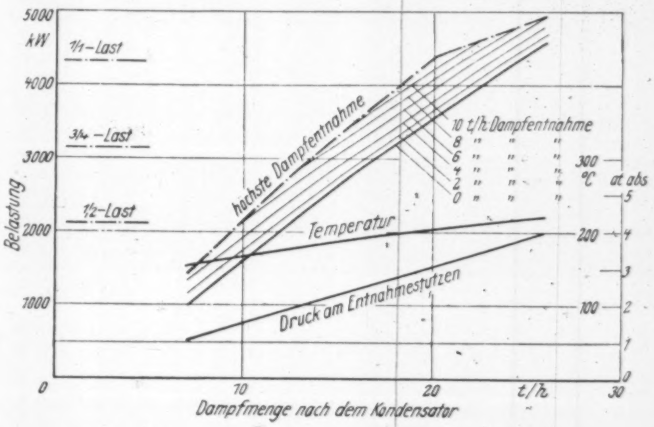


FIG. 2 PRESSURE AND TEMPERATURE AT THE EXTRACTION CONNECTION FROM THE FIRST STAGE OF A 4200-KW TURBINE

(Live steam, 14 atm gage, 325 C; cooling water temperature, 15 C; *Belastung* = load; *Dampfmenge nach dem Kondensator* = amount of steam back of the condenser; *hochste Dampfentnahme* = maximum extraction; *Dampfentnahme* = steam extraction; *Druck am Entnahmestutzen* = pressure at extraction point.)

Where extraction is controlled the steam passing the low-pressure part of the turbine is so throttled that the desired pressure at the point of extraction is available. However, this is accompanied by material throttling losses in the steam flowing through the low-pressure part to the condenser, and when the extraction is slight the efficiency of the turbine is adversely affected. With uncontrolled extraction the efficiency of the low-pressure part of the turbine is not affected.

It would appear from Fig. 3 in the original article that the extraction of the full amount of heating steam from the 10,000-kw turbine can be done only after 6 p.m. The rest of the time the extraction steam would be supplied by throttling live steam and from exhaust steam of the auxiliary turbine driving the condenser machinery. Thus in 1933 only 65 per cent of the demand for heating steam which amounted to 6513 tons could be supplied from extraction. To this had to be added 21,485 tons of live steam. Fig. 3 (original article) moreover shows that in many cases only a slight increase in pressure of the extraction steam would have been sufficient to make it possible to feed it into the heating system.

INSTALLATION OF A TURBO STEAM COMPRESSOR

The turbo steam compressor was designed by the Power Plant Co., of Heidelberg, for a compression ratio of 1.2 to 1.6, initial pressure of 2 to 4 atm abs, final pressure 2.5 to 5.5 atm abs; the machine runs at controlled speeds of from 8000 to 12,000 rpm. The actual machine was built by Brown, Boveri & Co., of Mannheim.

The compression process is shown in the form of a total-heat-entropy diagram,

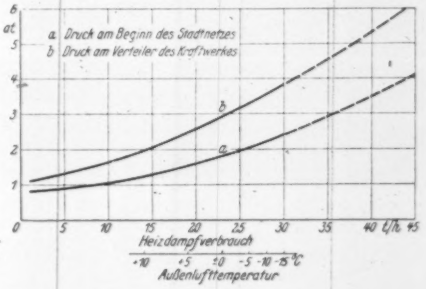


FIG. 3 STEAM PRESSURE AT THE ENTRY TO THE CITY SYSTEM (*a*), AND STEAM PRESSURE AT THE DISTRIBUTOR OF THE POWER PLANT (*b*) AS FUNCTIONS OF THE CONSUMPTION OF HEATING STEAM

(*a Druck am Beginn des Stadtnetzes* = pressure at the beginning of the city system; *b Druck am Verteiler des Kraftwerkes* = pressure at the distributor of the power plant; *Heizdampfverbrauch* = consumption of heating steam; *Aussenlufttemperatur* = outside-air temperature.)

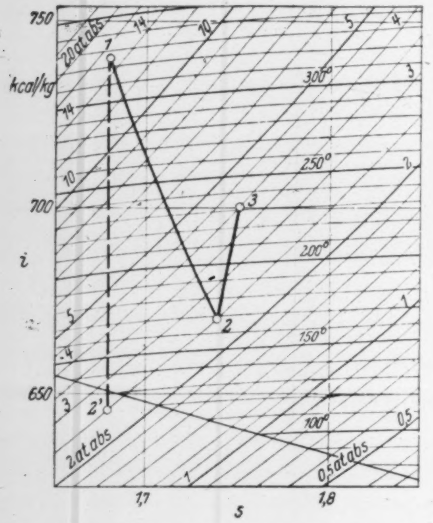


FIG. 4 PROCESS OF COMPRESSION OF EXTRACTION STEAM ON A TOTAL-HEAT-ENTROPY DIAGRAM

(Point 1, initial state of steam before entry to the turbine; point 2′, end-point of the adiabatic expansion down to extraction stage; point 2, actual terminal state in the extraction stage and state of steam at the entry to the compressor; point 3, state of the steam on leaving the compressor. Compression ratio 1:6.)

Fig. 4, plotted from data obtained in one instance during the acceptance tests.

Fig. 5 shows the guaranteed steam consumption of the driving curve of the compressor for various compression ratios. Acceptance-test data are plotted at all points where measurements showed a steam consumption lower than guaranteed. The drive curve at all times operates with a back pressure which corresponds to the initial pressure of the heating plant, which, in turn, is equal to the extraction pressure plus the rise of pressure produced in the compressor.

Fig. 6 in the original article shows the connections and layout of the plant and is not reproduced here.

The steam-compression machinery during the period when heating is required operates from 6 a.m. to 4 p.m. The final compression pressure is controlled electrically by varying the speed of the driving turbine. The steam compressor is driven by a constant-pressure turbine running on roller bearings. The turbine is supplied with main and safety governors working through oil pressure. It is designed to the following specifications: Initial steam pressure, 15 atm abs; inlet steam temperature, 330 C; back pressure up to 5.5 atm abs; speed about 12,500 rpm; output at the couplings, 260 kw. The centrifugal compressor, direct driven by the turbine, is supplied with steam from one side and has three stages. The shaft of the compressor runs in roller bearings. The compressor was designed (compare Fig. 5) for the following normal operating conditions: Steam received, 10 tons per hr; admission pressure, 2.5 atm abs; temperature of the steam admitted, 210 C; final compression pressure, 3.25 atm abs; temperature of the compressed steam, about 260 C; steam consumption of the driving turbine, 5700 kg per hr.

ECONOMY

The economy of the steam compressor is materially affected by the fact that it operates practically without losses, since the energy employed there, with the exception of very slight radiation losses, is recovered as useful heat in the compressed steam and as exhaust steam from the driving turbine.

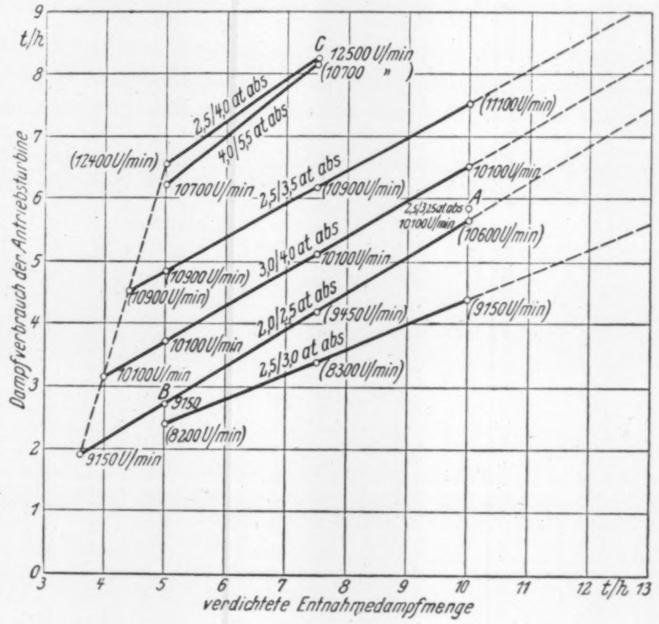


FIG. 5 STEAM CONSUMPTION OF THE TURBINE DRIVING THE STEAM COMPRESSOR AT VARIOUS COMPRESSION RATIOS

(*A*, normal operating conditions assumed as a basis of design; *B* and *C*, points guaranteed as to performance; ordinates, steam consumption of the driving turbine; abscissas, amount of extraction steam compressed in tons per hour; *U/min* = rpm.)

Assuming that even after the compression unit has been installed 6000 tons of throttled live steam must be expended in heating and that 5000 tons of live steam are needed to drive the turbines, 10,000 tons more than before of steam per year can be taken for heating purposes from the turbines by means of extraction. If it be assumed that average steam consumption of the 10,000-kw turbine in the high-pressure part is 13 kg per kwhr, approximately 770,000 kwhr can be generated per year from this extraction steam. Assuming an expenditure of 2 kg of brown coal per kwhr, the use of extraction steam as set forth would produce a yearly saving of 1540 tons. From this, however, must be subtracted the heat value of the work contained in the 770,000 kwhr, after it has been converted into terms of coal. This, at a turbine efficiency of 74 per cent, gives approximately 900 × 10^6 kcal, or at an evaporation of 2.6 times approximately 490 tons of coal, so that actually there is a saving of coal of about 1050 tons. This saving of coal is sufficient to provide 25 per cent of the value of the plant for interest and depreciation. There are no material maintenance costs involved. The extraction of 10 tons of steam per hr corresponds, with a steam consumption of 13 kg per kwhr, to an output of 770 kw from the high-pressure part of the turbine. The installation of a turbine compressor produces the same economic results as would the installation of a back-pressure turbine of the same output, but the former arrangement has the advantage that the operating main turbine does not lose a part of its useful load through the back-pressure action. (Carl Raubold in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 25, June 22, 1935, pp. 773–775, 6 figs.)

PUMPS

Tests of Water-Jet Air Pumps

THE water-jet air pump, notwithstanding its many advantages, such as low initial cost, high reliability of operation, slight attendance, and small floor space, is comparatively little used, partly because of its low efficiency and partly because hitherto there has been no reliable process of calculating the efficiency. Extensive tests made by K. G. Klöne have given certain relationships for the operation of jets and lead to conclusions as to the most economic proportioning and operation of the parts.

LOWER LIMIT OF VELOCITY

The delivery of air from a pressure of p_i kg per sq m prevailing in the jet housing to the pressure p_0 kg per sq m obtaining at the receiver tube end begins at a velocity of the water jet w_1 m per sec which has to be determined from the equation

$$\eta_d\left(h + \frac{w^2_{1I} - w^2_2}{2g}\right) = \frac{p_0 - p_i}{\gamma_W} + \zeta\,\frac{w^2_2}{2g}\ldots\ldots\ldots[1]$$

In this equation η_d indicates the efficiency of the receiver tube equal to the ratio of the actual increase of static pressure to the increase of static pressure at no-loss flow; h is the head of the water from the water nozzle to the end of the exit tube in meters ($h = 0$, if the jet is located horizontally); w_2 is the velocity of discharge of the mixture in meters per second at the end of the receiver tube; g the acceleration due to gravity in meters per second per second; γ_W the specific weight of water in kilograms per cubic meter; and ζ is the coefficient of friction of the cylindrical discharge pipe connected to the receiver tube; $\zeta = \lambda\, L/D$, where λ is a friction constant depending primarily on the characteristics of the surface; L is the length and D the diameter of the receiver tube.

AIR DELIVERY

The amount of air sucked in and delivered V_{L1} in cubic meters per second at a given velocity of water w_1 in meters per second, a constant pressure p_i and a constant temperature t_i, must be below a given velocity of water w_{1II} depending on the back pressure p_0, in accordance with the equation

$$\eta_d\left(h + \frac{w^2_1 - w^2_2}{2g}\right) = \frac{p_0 - p_i}{\gamma_W} + \frac{V_{Li}}{G_W}\,p_i \ln\frac{p_0}{p_i} + \zeta\,\frac{w^2_2}{2g}\ldots\ldots\ldots[2]$$

In this equation G_W is the amount of injection water entering the jet apparatus in kilograms per second. When the velocity of water is higher than w_{1II} the volume of air taken in by suction is independent of the back pressure and is

$$V_{Li} = G_W C(p_0 - p_s)\,w_1\ldots\ldots[3]$$

where C is a constant dependent on the design of the jet apparatus and p_s is the saturation pressure in kilograms per square meter corresponding to the prevailing temperature of water; V_{Li} is always dependent on the pressure and temperature prevailing in the jet apparatus. The value of C in tests with jet apparatus having a cylindrical receiver tube and a water temperature of 64 C was found to be 1.90×10^{-5}. In the case of a diffuser jet apparatus 2.18×10^{-5} at the same temperature of 64 C, and 1.97×10^{-5} in diffuser apparatus at a temperature of 23 C.

MOST DESIRABLE WATER VELOCITY

From what has been said it would appear that water-jet pumps have one region of operation dependent on and another independent of the back pressure. The velocity at the borderline between these two regions of operation is found to be

$$w_{1\,II} = \frac{Cg(p_i - p_s)}{\eta_d\,\gamma_W}\,p_i \ln\frac{p_0}{p_i} + \sqrt{\left(\frac{Cg(p_i - p_s)}{\eta_d\,\gamma_W}\,p_i \ln\frac{p_0}{p_i}\right)^2 + \frac{(p_0 - p_i)\,2g}{\gamma_W\,\eta_d} - 2hg + w^2_2\left(1 + \frac{\zeta}{\eta_d}\right)}\ldots\ldots[4]$$

With this velocity w_{1II} a jet pump of given dimensions works with the best efficiency η.

EFFICIENCY

The total efficiency

$$\eta = \frac{\eta_d G_W\left(h + \dfrac{w^2_1 - w^2_2}{2g}\right) - G_W\,\dfrac{p_0 - p_i}{\gamma_W}}{G_W\left(\dfrac{w^2_1}{2g\varphi^2} + h - \dfrac{p_0 - p_i}{\gamma_W}\right)}\ldots\ldots\ldots[5]$$

increases rapidly from zero with an increase in the velocity of water up to a velocity w_{1I} reaches a maximum at w_{1II} and falls off thereafter. φ is a constant which serves as a measure of the reduction of the theoretical discharge velocity w_{th} to w, because of the presence of liquid friction in the water nozzle; in other words $w = \varphi w_{th}$. When plotted the η-curve has a sharp peak at w_{1II}. The maximum efficiency belonging to w_{1II} increases with increasing internal pressure p_i and also with increasing velocity w_{1II}.

MOST FAVORABLE RATIO OF NOZZLE AND RECEIVER-TUBE CROSS-SECTIONS

The efficiency of the receiver tube η_d is determined by the ratio of cross-sections m = ratio of cross-section of water nozzle to final cross-section of the receiver tube, and increases with increase of m from $m = 0$, first rapidly, and then much slower.

The exit energy grows simultaneously as the square of m (complete equation given in the original article). A certain optimum value $m_{\text{opt.}}$ is reached at a point where the exit loss balances exactly the gain of energy in the receiver tube η_d. The most favorable ratio of cross-sections obtains in the case of water-jet air pumps with cylindrical receiver tubes approximately at $m_{\text{opt.}} = 0.34$ and in pumps with diffusers at about $m_{\text{opt.}} = 0.19$.

The efficiency η_d is approximately equal to 0.6 for jet pumps proportioned in that way, both with diffusers and with cylindrical receiver tubes. The former give a better energy utilization than the latter, since in the first place the exit loss $w_2{}^2/2g = m\,w_1{}^2/2g$ is smaller, and next because the constant C is greater. According to Equation [4] when C increases, $w_{1\,II}$ increases also, which improves the efficiency η.

INFLUENCE OF WATER TEMPERATURE

The overall plant efficiency η is favorably affected by the use of water as cold as possible, because with decrease of the temperature of water C increases and p_s decreases according to $w_{1\,II}$, Equation [4], and hence η, increases.

Equations for saturated and unsaturated air are given in the original article. Limitations of apparatus used by the author did not permit experimenting with high vacuua. The region tested as to pressure p_i from 3200 to 9600 kg per sq m; water temperatures from 60 to 70 C and pressures between 1500 and 3200 kg per sq m at 23 C. (K. G. Klöne, dissertation presented to the Technical High School at Darmstadt in 1932 published in 1934, abstracted in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 3, Jan. 19, 1935, pp. 77–78)

TESTING AND MEASUREMENT

New Process for Testing Resistance to Cracking of Metallic Materials

CRACKING of brass has been known for a long time and the same phenomenon was encountered in other metals. Of late it has been found on many occasions that cracking has been observed in light metals, and the practical applicability of several new aluminum and magnesium alloys has been materially affected by their tendency to crack. The author illustrates this statement by a number of instances, from which he proceeds to a discussion of standard tests and then a new test which he has developed. He points out that processes for testing a material in respect to its mechanical stressing where the metal is simultaneously subjected to corrosion are as yet little developed. In the majority of cases the material is exposed to corrosion while in a state of stress believed to correspond to practical conditions. The material then either cracks after a certain period of time or remains unaffected.

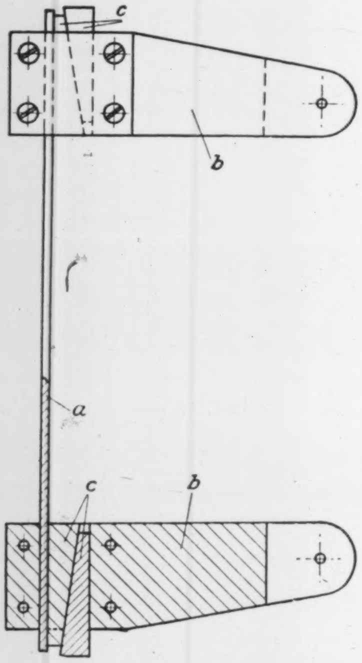


FIG. 6 TESTING APPARATUS FOR INDUCING A BENDING STRAIN IN A PRISMATIC TEST BAR

With this kind of testing there is no precise information as to the magnitude and kind of the stresses induced in the material, although in engineering periodicals two tests have been described in which the stresses have been calculated analytically from the magnitude of deformation. (The author refers here to the paper by Hatfield and Thirkell on "Season Cracking," before the Institution of Metals in London, 1919, vol. 12, p. 67.) He criticizes briefly this work and points out that the successful determination of stresses is based on the assumption of validity of the Hooke law, which means that in the case of materials with a low limit of elasticity the method can be applied only within very small ranges, which makes it often of no interest practically.

In the new process the apparatus shown in Fig. 6 is used. To the ends of a prismatic test bar are attached, by means of double wedge connections, at right angles to the axis of the test bar, levers about 80 mm long. These levers consist of an insulating material (artificial resin). The purpose of which is to prevent the contact of the test bar during corrosion tests with other metals or their corrosion products. The test bar is next subjected to the forces acting through a testing machine on the ends of the levers in a direction parallel to the axis of the test bar. In one of the illustrations (Fig. 11 of the original article), is shown an arrangement wherein the forces are of such a character that they bend the test bar outward, but the test bar can also be bent inward by oppositely directed forces.

The bending stress uniformly distributed over the entire length of the test bar may be computed from equation $\sigma = 8P/W$ kg per sq cm if the length of the level is $l = 80$ mm. Here P is the load in kilograms, read from the testing machine, and W is the moment of resistance of the test bar in cubic centimeters. By means of a simple scale which can be set up on the apparatus, the amount of bending can be measured.

The test bar, together with its stressing and measuring devices, may now be taken out of the testing machine and the desired bending stress induced by having the ends of the levers brought together a certain amount by means of a metal rail as shown in Fig. 12 in the original article.

In this way the same amount of bending of the test bar is obtained as was observed when the bar was in the testing machine. It is for this purpose that the metal rail has been provided with a number of little holes to receive the nuts and bolts necessary to hold the lever ends in the desired spacing. In this condition the test bar is subjected to a corrosion attack and the time that is necessary to produce cracking or complete rupture of the test bar is determined. This arrangement permits also the testing of bars for the characteristic relationship between the duration of exposure to corrosion required to produce fracture and the magnitude of the bending stress. A number of aluminum and magnesium alloys enumerated in the original article by their German trade names have been tested.

The following brief references to the extensive original data are made: Duralumin, lautal, and some other metals did not crack after a 12-month test period. On the other hand, the same duralumin and lautal test bars, hardened in a warm state, have shown exceptionally heavy corrosion, and a microscopic investigation indicated a pronounced intercrystalline corrosion attack. In the test bars of the same metal hardened at room temperature no intercrystalline corrosion has been observed.

In the case of grained dural the corrosion attack was limited entirely to a surface layer of little importance from the point of view of strength of materials. Notwithstanding its slight thickness, about 0.1, mm, it was not eaten through by corrosion after a period of twelve months. The granular structure of the material remained completely unaffected.

This observation is all the more remarkable because the grained dural test pieces were deliberately so heat-treated (hardened warm) that the granular structure was in a state apparently unsatisfactory from the point of view of resisting corrosion. It would appear, therefore, that graining in itself represents good protection against faulty heat treatment of the material.

Another surprise of this investigation was that the hydronalium test pieces showed intercrystalline corrosion in places, though this did not go as far as in the case of warm-hardened duralumin or lautal test pieces. When the test piece has been polished and etched with a 9 per cent phosphoric-acid solution, fine strips running in the direction of rolling could be seen. It would appear that when in this state of crystallization hydronalium is particularly subject to intercrystalline corrosion.

As a summation it may be stated that:

(1) Cracks appear the earlier the higher the stresses imposed on the metal. Of two test pieces made of lautal hardened for 8 hr at 140 C the one stressed with 18.5 kg per sq mm cracked after four months and the other stressed with 13.2 kg per sq mm after nine and one-half months.

(2) In the case of duralumin and lautal hardened at room temperature, no tendency toward cracking was observed. If these metals, however, are hardened at higher temperature, for example, 180 C, they develop a strong tendency to cracking.

(3) In the case of hydronalium when in a state established in these tests intercrystalline corrosion appeared after a period of twelve months. (P. Brenner, Report No. 35/05 of the German Aeronautical Testing Laboratory, abstracted through *Luftfahrtforschung*, vol. 12, no. 3, June 17, 1935, pp. 107–115, 24 figs.)

THERMODYNAMICS

Effect of Baffles on Temperature Distribution and Heat-Transfer Coefficients of Finned Cylinders

AN investigation was made to determine the effect of baffles on the temperature distribution and the heat-transfer coefficient of finned cylinders. The tests were conducted in a 30-in. wind tunnel on electrically heated cylinders with fins of 0.25- and 0.31-in. pitch.

Four types of baffles were tested: Plates mounted at various positions around the cylinder and at various angles with respect to the air stream; streamline baffles mounted near the rear of the cylinder; shell baffles with variously shaped openings mounted around the test cylinder symmetrically with respect to a plane through the axis of the cylinder and parallel to the air stream; and integral baffles composed of strips welded to the tips of the fins of the test cylinder to form passages between the fins through which the air could flow to the rear of the cylinder.

The results of these tests showed that the use of integral baffles gave a reduction of 31.9 per cent in the rear-wall temperatures and an increase of 54.2 per cent in the heat-transfer coefficient as compared with a cylinder without baffles.

Although the effects of the shell baffles were not equal to those of the integral baffles, they gave a large reduction in rear-wall temperatures and a large increase in the heat-transfer coefficient. The best results were obtained with the shell baffles mounted in contact with the fins, when the intake opening was equal to the arc subtended by an angle of approximately 145 deg, when the extensions were 3 in. or more in length, and when the ratio of exit area to area between fins was approximately 1:6. The heat-transfer coefficient with the best shell baffles varied as the air speed to the 0.85 power. (Oscar B. Schey and Vern G. Rollin, Report No. 511 of the National Advisory Committee for Aeronautics, 1934, 13 pp., 21 figs.)

VARIA

Atmospheric Pollution

THE twentieth report on the subject of atmospheric polution has recently been issued by the Department of Scientific and Industrial Research (Great Britain). For obtaining a measure of sulphur pollution a procedure is used in which cylinders coated with lead peroxide paste are exposed and withdrawn for analysis of the coating at the end of a month, new cylinders being substituted. These tests have been sufficiently advanced to warrant the department in accepting the method as a standard one. It is particularly to be recommended where it is desired to maintain observations at a number of points in a particular neighborhood without undue cost and is not intended to supersede the earlier method recommended by the committee for the determination of sulphur gases where it is desired to determine the sulphur concentration of the gases in the air and its variation from day to day.

A method for measuring daylight is being developed. The light is caused to fall on a photoelectric cell and the resulting current charges a condenser, which, when the charge reaches a definite amount, discharges through a neon lamp causing an ordinary four-figure counter to move forward one unit. When perfected, this method should prove a welcome addition to the means at the disposal of the cooperating authorities for estimating the loss of light caused by smoke pollution. The instrument can be fitted with suitable filters to measure either visible or ultra-violet light.

The measurement of smoke from chimneys has continued to occupy attention. It would appear that the mean of a number of readings with a photoelectric instrument used in measuring daylight at quarter-minute intervals gives the true darkness of the smoke within 25 per cent. This corresponds with a quarter of one Ringelmann number and is likely to be sufficiently good for most purposes. (The Investigation of Atmospheric Pollution, published by His Majesty's Stationery Office (Great Britain), abstracted through *The Steam Engineer*, vol. 4, no. 9, June, 1935, pp. 359–360)

Engineers and Economics

A SYNOPSIS of the First Interim Report on Schemes and Proposals for Economic and Social Reforms of the Engineers' Study Group on Economics presented before the British Science Guild, May 16, 1935.

The report is divided into three sections. First, the genesis and aims of the group are briefly outlined. Then follows the report proper, which groups and classifies under various headings the first 24 schemes and proposals for economic and social reforms examined by the group. In the third section the present paradox of "Poverty Amidst Potential Plenty" is discussed, together with the method of approach by which it is hoped a constructive solution of the existing economic chaos may be found.

The Engineers' Study Group on Economics is a body of qualified engineers, scientific workers, and others concerned with the fact that the community is not enjoying in general a standard of living and endowed leisure commensurate with what has been made potentially possible by modern science and technology. The group was inaugurated as a result of the discussion on "Can Engineers Reduce Unemployment?" at the informal meeting at the Institution of Mechanical Engineers on January 20, 1933. It determined to approach economics as an engineering problem, by methods of scientific investigation, analysis, and synthesis. The group organized into two main sections: (*a*) To examine present and potential production to determine what the practicable minimum standard of living could be; (*b*) to examine, analyze, and ultimately criticize proposed schemes of economic reform.

Selection of the first 24 sets of proposals examined was arbitrary; many more await investigation. There are included the economic proposals of all the existing political parties and the new régimes in Europe and the United States; of economists (e.g., Keynes and Blackett); industrialists (e.g., Melchett and Macmillan); monetary reformers (e.g., Douglas and Gesell); responsible authorities (e.g., London Chamber of Commerce); and others. Short summaries of the schemes are presented as appendixes, together with separate treatment of orthodox economics. Classification of the schemes is first made under three headings, viz: (1) Monetary; (2) industrial planning; (3) industrial planning and monetary. This grouping provides not only differentiation between proposals aiming at control of money and control of industry, but also permits their consideration from the standpoint of immediate practicability. A second classification is based on diagnosis and cures. The former include lack of purchasing power in one form or another, uncoordinated individualism, the profit motive, and the private ownership of the means of production; and the latter range from simple measures of monetary reform to complete economic unification of the whole nation. A third classification is presented from the standpoint of radicalism. In this is examined the extent of the changes envisaged by the different schemes in administrative application, alterations in the economic structure, and their ultimate sociological effects. Finally, the schemes are discussed in relation to (1) employment of endowed leisure, and (2) economic liberty. (*The Steam Engineer*, vol. 4, no. 9, June, 1935, p. 384)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Part Played by A.S.M.E. in New Steamship Boiler Rules

To the Editor:

Copies of Amended Rules I and II of the U. S. Department of Commerce, Bureau of Navigation and Steamboat Inspection, pertaining to the design, construction, and inspection of boilers, unfired pressure vessels, and the appurtenances thereof, have been sent to steamship owners, shipbuilders, boiler and steel manufacturers, classification societies, and other persons or organizations connected with marine industry, and United States supervising, traveling, local, and assistant inspectors, of the Bureau of Navigation and Steamboat Inspection, with a circular letter stating that they will become effective July 1, 1935. In the circular letter Director J. B. Weaver acknowledged the valuable aid and cooperation of fourteen different organizations. The part taken by the A.S.M.E. was as follows:

Ex-President Herbert C. Hoover, when Secretary of Commerce, sponsored the American Marine Standards Committee which, among other assignments, was to prepare rules covering the construction of marine boilers. The American Society of Mechanical Engineers was invited to cooperate. The invitation was accepted and the Boiler Code Committee appointed what was later known as the Special Committee on Marine Boiler Rules.

At a meeting of the subject subcommittee of the American Marine Standards Committee on "Rules for Boilers and Pressure Tanks," held March 31, 1926, the Hon. Dickerson N. Hoover, then supervising inspector general of the Steamboat Inspection Service, made it plain that the Service wished to adopt rules that would be thoroughly up to date. He suggested that a review be made of all established codes, with the idea of preparing a set of rules which would be the best of all and that an endeavor be made to have the law modified, if found necessary, to permit adoption by the Steamboat Inspection Service of these rules as a whole.

The American Marine Standards Committee issued a set of rules in 1929 for the design and construction of marine boilers and pressure vessels. The Boiler Code Committee, to whom this report was referred by its special committee, took the position that it should be made more complete so as to give comprehensive rules for all of the usual types of boilers employed in marine service.

In view of the fact that the code which was being prepared by the American Marine Standards Committee did not seem to meet the requirements of the Steamboat Inspection Service, the Steamboat Inspection Service prepared a tentative set of rules of its own which it submitted to the A.S.M.E. Boiler Code Committee for comments and suggestions. These rules included all types of boilers ordinarily used in marine service. The Boiler Code Committee reported that it considered the rules to be prepared along proper lines and commended the Steamboat Inspection Service for preparing a more complete set of rules.

The American Marine Standards Committee, acting through the Society of Naval Architects and Marine Engineers, petitioned the Hon. L. P. Lamont, then Secretary of Commerce, to recognize its boiler rules as the standard. At the suggestion of Secretary Lamont a committee was organized to coordinate the two sets of rules which had been prepared. This committee, known as the Committee to Coordinate Marine Boiler Rules, was formed by requesting a number of societies to appoint representatives. Capt. Walter M. McFarland, who was not originally a member of the committee, was appointed chairman. The members of the committee and the organizations which they represented were as follows: W. M. McFarland, chairman, past-president, Society of Naval Architects and Marine Engineers; H. L. Seward, secretary, Society of Naval Architects and Marine Engineers, and American Bureau of Shipping; Charles F. Bailey, National Council of American Shipbuilders; John L. Crone, Bureau of Navigation and Steamboat Inspection; D. S. Jacobus, past-president, The American Society of Mechanical Engineers; B. E. Meurk, American Steamship Owners' Association; and H. C. E. Meyer, American Marine Standards Committee. Members of the subcommittee were: J. Bergvall, American Bureau of Shipping; A. V. Bouillon, American Marine Standards Committee; and J. W. Wilson, Bureau of Navigation and Steamboat Inspection. Captain McFarland and Mr. Bouillon are now deceased.

In the formulation of the code a draft was first prepared by Mr. Bergvall and Mr. Wilson, who had the cooperation of Mr. Bouillon in a few of the early sessions.

Captain McFarland was an ideal chairman, his attitude in conducting the meetings being well expressed in the preamble which he prepared for the report of the committee, a paragraph of which reads as follows:

> A guiding principle from the beginning has been that the code should represent the unanimous opinion of the committee. In other words, if differences of opinion arose, they were to be smoothed out and settled by unanimous vote. With great satisfaction the committee can assert that this result has been accomplished.

The rules sanction the fusion-welding of drums or shells. This section was prepared by a committee on welding in marine construction of the American Welding Society, and was based on the rules prepared by the A.S.M.E. Boiler Code Committee with the cooperation of the American Welding Society.

The report of the committee was published by the U. S. Department of Commerce and issued April 15, 1933, as the First Report of Committee to coordinate Marine Boiler Rules as approved by the committee. Copies of the report were sent to a number of interested parties with the request that discussion be submitted for the guidance of the committee in preparing a final draft. Mr. Wilson did most valuable work in conferring with many organizations and with experts in various fields.

The last meeting of the committee was held in New York City, August 13, 1934, in general session with the A.S.M.E. Special Committee on Marine Boiler Rules and other interested parties. At this meeting all of the questions that were still open bearing on revisions were discussed and an agreement reached regarding the way in which they should be handled.

The Hon. D. N. Hoover did heroic work in preparing and securing the passage of a bill to amend the laws relating to construction and inspection of boilers to free the Bureau of Navigation and Steamboat Inspection of certain objectionable legal restrictions and to allow the use of the more exact and consistent rules that were being prepared by the committee. This made it possible for the Bureau of Navigation and Steamboat Inspection to prepare a revised set of rules for its use based on the report of the coordinating committee. These rules, as already stated, have been issued as Amended Rules I and II, General Rules and Regulations of the Bureau of Navigation and Steamboat Inspection, and are a fine example of what can be done by cooperation and by enthusiastic and painstaking effort of those doing the work.

D. S. JACOBUS.[1]

The Pivoted-Motor Drive

TO THE EDITOR:

The paper by Robert R. Tatnall[2] ably presents the mathematics involved in the design of motor bases and drives and discusses the performance on one type of motor base. The writer's interest in changes in performance resulting from different locations of the pivot axes of motor bases resulted, after preliminary experiments and calculations, in establishing the conclusion that for good performance the pivot axis of a motor base should be between the plane of the motor feet and the motor shaft.

The term "good performance" is understood to mean the correct tension at peak load automatically decreasing to almost zero at no load. This condition is approximated when the gravity component $eW/(a + b)$ of Dr. Tatnall's Equation [3] is small, and the reaction-torque component $bkP/(a + b)$ of the same equation is large. The writer believes that the ideal condition would be that of a practically constant tension ratio different for each type of belt and pulley-center distance ratio and of such value that true slip would not occur. In designing such a base with the pivot axis above the plane of the motor feet, it was found that the angle of the center line of the drive was a large factor in actual performance, and that this type of base produces a belt tension which varies through a wide range with changes in the load. Dr. Tatnall's formulas apply equally well to this type of base and to the type with the pivot axis below the plane of the motor feet.

For down drives and some reverse drives from motors mounted on bases pivoted above the plane of the motor feet, a counterweight of such a size should be used that its weight times its lever arm is greater than the moment of the motor weight times its lever arm for down drives and less than the motor moment for upward reverse-direction drives. This provides a small initial gravity tension.

As the pivot axis of the motor base approaches the motor axis, the reaction-torque component $bkP/(a + b)$ of Dr. Tatnall's Equation [3] usually increases and the motor weight becomes less important. Therefore, with the pivot axis higher than the motor feet, successful drives can be made for those conditions for which drives cannot be made when the motor base is pivoted below the motor feet.

The importance of the location of the pivot axis is clearly shown by the drawing of the locus of pivot points, Fig. 8 of Dr. Tatnall's paper, in which a pivot point located any place on the line *AB* gives a tension ratio of 4.3 at 37.5 hp. With the pivot point located at *Q* below the plane of the feet of the motor, the gravity component $eW/(a + b)$ is relatively large and the reaction-torque component $bkP/(a + b)$ is small, and the performance is poor.

If the pivot point were located above the motor feet at the intersection of the locus line *AB* and the tight belt strand, T_2 would remain constant regardless of the load, and the increase in total tension would be the same as the increase in the effective tension. Performance would be good because the change in total tension from no load to peak load would be large, and it would be obtained without the reverse belt bending and the idler-bearing losses resulting when idler drives are used. Higher bearing pressures would, however, be necessary at peak loads because of the smaller arc of belt contact, but average bearing pressures would be greatly reduced.

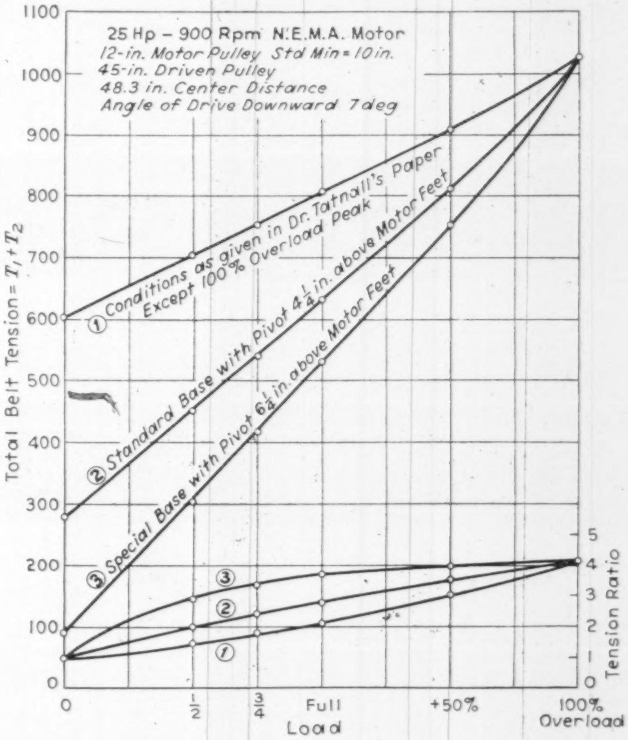


FIG 1 MOTOR BASE PERFORMANCE

If the pivot axis were located at *A*, the gravity component of total tension $eW/(a + b)$ would equal zero and all the belt tension would be produced by reaction effect. With this pivot-point location, initial tension would be zero and the tension ratio at 37.5 hp would be 4.3.

It is the writer's contention that the average load on many motor drives is often as low as 25 per cent of the peak load and since a drive must be belted for the peak load, large savings in bearing-friction losses, bearing maintenance and replacement expense, and belting costs are effected by a scientific location of the pivot axis of the motor base. Using a motor base with the pivot axis above the plane of the motor feet and the same drive conditions given by Dr. Tatnall, except that a peak load of 100 per cent overload is used, the results of the problem would be as shown in the accompanying Fig. 1.

From this discussion, it is concluded that (1) the larger the difference between peak load and average load, the larger the savings possible with the use of a motor base with the pivot axis located above the plane of the motor feet, (2) since the gravity component $eW/(a + b)$ of belt tension is relatively unimportant with pivot axis above the motor feet, vertical or near vertical drives with small motor pulleys are possible with the reaction-torque base and usually impossible with the gravity base, (3) drives with vertical motor shafts are possible only with the reaction type of base, and (4) because of the much lower average belt tension produced by the reaction-torque base, smaller pulleys and less belting may be used. This is sometimes important when the driven pulley is fixed as to diameter and face.

---

[1] Chairman, Executive Committee of the A.S.M.E. Boiler Code Committee, Past-President, A.S.M.E.

[2] See MECHANICAL ENGINEERING, May, 1935, pp. 287–291.

WALTER J. COPPOCK.[3]

TO THE EDITOR:

The writer learned when first installing pivoted drives seven or eight years ago that it was incorrect to assume a simple moment of forces about the pivot shaft, with the weight of the motor counterbalancing a mean resultant of the belt tensions through the shaft centers. As a result, tests quite similar to those recorded by Dr. Tatnall in his Fig. 3 were undertaken which lead finally to a mathematical solution substantially the same as Dr. Tatnall presents. While the writer generally uses for convenience the graphic method for solving such problems he has found the anticipated transmitting capacities seldom out of line with those later obtained in practice.

In only one respect does the writer's experience vary slightly from the author's and that is in the use of higher ratios of belt tension for paper pulleys and best-quality leather belts. Where Dr. Tatnall uses a slack- to tight-side tension ratio of 1 to $6^{1}/_{3}$ at a 180-deg contact arc, the author uses a ratio of 1 to 9. With so high a ratio, however, it is necessary to be more careful in making allowances for such unfavorable factors as dirt, grease, and dust that may affect values of the coefficient of friction between belt and pulleys. The writer also deems it advisable in figuring drives to design them to take care of full starting torque of the particular motor being used.

The writer hopes that plant men are not going to feel that the pivoted motor drive based on Dr. Tatnall's article is too technical and therefore not suitable for average shop use. This would be most unfortunate and certainly is not borne out by the writer's experience. In any belt drive, the capacity of the belt is proportional to the pressure of the belt against the pulley and all the shop man really needs to know is that greater belt tension can be obtained by moving the motor further from its pivot location, and conversely that less belt tension can be obtained by moving the motor closer to its pivot location. He will find this adjustment for the great majority of drives, say 10 to 15 hp and less, can be made on the job with full assurance that the drives will perform satisfactorily without the necessity of making diagrams or calculations. For large drives or those falling in the class of occasional freak conditions, a complete layout can be made by an experienced man in fifteen to thirty minutes following Dr. Tatnall's outline. This is not an unreasonable amount of time to spend in solving such a problem, particularly since little if any further adjustment may then be necessary when the drive is installed, and since in any event such calculations may be required for the economical determination of important dimensions such as belt length and location of foundation bolts.

W. D. HAMERSTADT.[4]

Steel-Plant Lubrication

TO THE EDITOR:

I assume the oil lubrication for speed-reduction sets and mill pinions referred to in the papers by Mr. Burrell[5] and Mr. Pelley[6] is the standard refinery product. If mill equipment were always lined up perfectly and the mechanical conditions properly maintained continuously, the ordinary standard lubricants would serve to better advantage, but frequently the equipment is not lined up properly. More frequently, through the stresses of operating demands, machines get out of alignment, and the operating schedule will not permit of corrections being made promptly. Therefore, special lubricants must be used to protect the equipment.

Mr. Burrell states that these standard refinery oils work best with gears of the higher carbon and hardened types. This is true, and it emphasizes the fact that other kinds of machined gears and all types of gears that are not serviced adequately require special lubricants to carry the loads and absorb the shocks to prevent them from cutting, pitting, and wearing unduly.

It is also mentioned by Mr. Burrell that standard types of refinery products are used for the greater part of the lubrication in the mill with which he is connected. This is probably approximately so in most all steel plants, especially if the refinery residium shields are included. An attempt has been made to set up the approximate proportionate costs of standard and special types of lubricants used in steel mills. Of the total costs it is calculated that the consumption of standard refinery products amounts to about 85 per cent, and the special lubricants about 15 per cent. The latter are used chiefly for the major machinery investment.

"Maintenance" includes all factors of efficient, and economical machinery operation, design and quality of machines, lubricants and application methods, quality and quantity of production. There is another factor of important influence, i.e., self-interest or incentive. In a budget and bonus plan the management sets up a monthly budget for each operating group, which provides for the distribution of a liberal portion, divided among all members of the mechanical department, of the savings made on the upset budget. As one means of making all workmen realize the cost, the value of the supplies used, requisitions include the cost of the parts and supplies as well as the quantities. As the men have a personal interest in keeping the costs down, the supplies are not over-ordered or wasted. Of greater importance is the fact that closer attention is given to the condition of the equipment to prevent its getting out of repair—far less costly than curatives.

In one mill, for the past ten years or more, it has been a fixed practice to make frequent periodical inspections of all major units, as a rule every week end, especially when starting up new equipment. By this plan, if things are not right, the trouble can be caught before it goes too far. This duty is left generally to the assistant millwright or chief greaser, who reports minor difficulties to the department master mechanic, and if serious, to the general master mechanic, who directs corrective measures. Every one knows of large, costly equipment that is seldom inspected unless there is trouble. By this lack of attention, unnecessary wear and destruction can go on for a long time, and to a point where correction, if not impossible, will far exceed the cost of frequent inspections and the proper care.

The steel and all major industries are in great need of more trained practical lubrication engineers—men with greater and a more accurate understanding of lubricant characteristics and methods of applying, required to meet the various and varying demands and conditions, with a sufficient knowledge to make intelligent selections, and with the authority to requisition—and get—the kinds of lubricants which in their judgment are needed.

---

[3] Sales Engineer, The American Pulley Company, Philadelphia, Pa. Assoc-Mem. A.S.M.E.

[4] Vice-President, Rockwood Manufacturing Company, Indianapolis, Ind.

[5] "Steel-Plant Lubrication," by B. S. Burrell, MECHANICAL ENGINEERING, July, 1935, pp. 415–417.

[6] "Steel-Plant Lubrication," by J. F. Pelly, MECHANICAL ENGINEERING, January, 1935, pp. 25–30.

The mechanical-department executives that I know of in the steel mills, with a practical knowledge of lubricants, who treat the subject seriously, who have the authority to specify and get the lubricants they need, can be counted on the fingers of one hand—not including the thumb. There are many fine, technically trained young men with the title of "lubrication engineer" who take their work seriously, but who are limited in practical experience and, what is worse, smothered by the lack of authority. With it they would undoubtedly make some mistakes, but they would not make the same mistakes again, and the investment would be profitable. There are others with sufficient practical experience to do a real job if they could get the proper materials and devices to work with. Officials in a position to designate sources of supply cannot know how little the purchase of special lubricants would affect their reciprocal arrangements, and how costly the use of unsuitable lubricants is to them, or they would not interfere with the rights of the operating departments.

W. D. HODSON.[7]

Modern Cast Iron

TO THE EDITOR:

The possibilities of special cast irons as automotive materials are being given increased attention. Therefore, Mr. McElwee's account[8] of what has been done in the foundry in their development is timely.

Certain foundries making automobile castings have made noticeable advances in recent years, both as to variety and uniformity of product. Likewise, in the past few years, automobile engineers have demanded more and more of the foundries and have asked for better castings of higher and more constant hardness. Alloys have been added and specifications established in the attempt to make cast-iron products keep pace with the steels and non-ferrous materials in meeting new and more difficult service requirements.

The foundries have been able to demonstrate that their new irons are practical and are not playthings of the foundry laboratory. Automobile parts formerly made from steel forgings are now cast successfully on a high-production basis. However, in comparing the products of the foundry with the steels, certain limiting factors cannot be overlooked. A product used in the "as cast" condition is necessarily subject to a lack of opportunity for controlling or eliminating defects that makes for a wider range of physical properties. Definite specifications can be written, but they will be met with greater difficulty.

For example: Mr. McElwee discusses the importance of selection of source. Two foundries working to the same specification and making the same automobile part will probably produce castings of different combinations of properties. Now, if the cast products represented only an initial stage in the manufacture and were given all of the selective and refining operations given to heats of steel, the output of the two sources would, no doubt, more nearly agree. Do we not have to recognize the limitations imposed by whether the iron is made in the cupola or electric furnace, whether it contains alloys or no alloys, or whether or not it receives later heat treatment?

We do not intend to discredit in any way what has been accomplished, but it is known that when the spotlight of publicity is thrown on new metallurgical material, we all become overenthusiastic and pass up certain fundamentals in balancing properties against requirements.

We agree in general with Mr. McElwee in his remarks on the use of alloys in cast iron. Nowadays there seems to be a greater tendency to accomplish results that will satisfy service requirements as far as possible without making alloy additions. We are inclined to believe that this change in attitude is due perhaps to the increased knowledge held by foundrymen. In the earlier years when we did specify alloy in some of our automobile castings, it is questionable whether or not we could have obtained iron to meet our service requirements without the alloy.

Is Mr. McElwee in favor of the standardization of specifications for cast-iron standards such as are issued by the S.A.E. for steels, granting his arguments as to undesirability of inclusion of chemical limits? This subject of standardization of cast irons has received considerable attention of late. From the standpoint of the foundryman I can see some advantages. For example: We, as a user, might be specifying one material, and for the same part, or a similar part, some other user might be specifying a different material. If we had a standard specification, the foundryman could use one iron on both applications. On the other hand, in my opinion, standardization of specifications implies a completeness of development. I wonder if we have arrived at such a stage. Standardization at this time might hamper further progress.

E. W. UPHAM.[9]

TO THE EDITOR:

High-test cast iron has been frequently recommended as a material for making a number of important parts in the automobile. It is my intention to discuss rather briefly the considerations which govern the use of this material in some typical applications, such as the camshaft, the crankshaft, the cylinder block, the differential carrier, and brake drums.

The use of special cast iron for camshafts has been fairly thoroughly tested, having seen service in recent models of a number of cars. The points which will finally determine whether the cast camshaft will ultimately replace the forged camshaft are ultimate cost and whether it will be possible to obtain sufficient uniformity of hardness and structure in the chilled cams. I have seen some results which lead me to believe that greater durability could be obtained by using a roller-cam follower which would permit the use of a more rounded cam nose.

Considerable experimental work has been done in connection with the use of high-strength cast iron for crankshafts. The most important factors to take into consideration in this application are the transverse and torsional moduli of elasticity of the material because these determine what the design must be in order to prevent undue deflection and torsional vibration of the crankshaft. The modulus of elasticity of high-strength cast iron being considerably lower than that of steel, it becomes necessary to modify the crankshaft design so that deflections and twisting of the crankshaft are no greater than are permissible with a steel crankshaft. In such a design of a cast-iron crankshaft in which deflections are not greater than permissible in a steel shaft, the unit stresses induced will be lower than in the steel crankshaft because for equal stresses a material of lower modulus of elasticity will deflect more. In the designing of cast crankshafts it is possible to take advantage of the use of certain shapes which are economically more possible in a casting process than in a forging process. This may permit a more advantageous distribution of material which would result in a more satisfactory crankshaft than could be obtained for the same cost by the forging process.

---

[7] President, General Manager, Hodson Corporation, Chicago, Ill. Mem. A.S.M.E.

[8] "Modern Cast Iron," by R. G. McElwee, MECHANICAL ENGINEERING, July, 1935, pp. 429–430.

[9] Chief Metallurgist, Chrysler Corporation, Detroit, Mich.

The question frequently arises as to whether it would be possible, by using high-strength cast iron for the cylinder block and crankcase, to reduce the weight of these parts sufficiently to make a cost saving. This does not appear a likely possibility. In the first place many of the sections in cylinder-block and crankcase castings are just as thin as it is possible to cast with ordinary gray iron. It would not be possible to reduce the thickness of these sections by using high-strength cast iron. If it were possible to reduce all of the sections of the cylinder-block casting, the saving would not be in proportion to the difference in tensile strength if it were desired to maintain the same stiffness of the casting as made in ordinary gray iron.

Although the high-strength cast iron may be twice as strong as ordinary cylinder iron, its modulus of elasticity is only about 19,000,000 compared to 12,000,000 to 14,000,000 for cylinder iron. But the possible saving is not even in this proportion because the stiffness of the section depends on the moment of inertia which varies with the cube of the thickness of the section. Consequently, taking all these things into consideration, the eventual weight saving possible would be in the neighborhood of 8 to 10 per cent. The cost of manufacturing and machining the high-strength cast iron would prevent any cost saving due to a weight reduction of eight to ten per cent.

Where the question of wear, however, is of prime importance, then advantage can be obtained by the use of some form of high-strength or heat-treated cast iron. The use of such materials for cylinder-block liners for trucks and busses has been an important factor in greatly reducing the cylinder wear.

Another application frequently suggested is the substitution of high-strength cast iron in the place of malleable iron for differential carriers. This is usually suggested with the idea in mind of reducing cost but has not made much headway. Even though the cost of the casting may be somewhat lower, the overall cost will not be favorable to the high-strength cast iron because of the great difference in machinability between the malleable iron and high-strength cast iron. Some apprehension is felt in connection with the use of cast iron for this part when riveting of other members to it is involved. Otherwise, high-strength cast iron would be a suitable material for this part.

One of the most important uses of high-strength cast iron on the automobile is for brake drums. There has been a great variety of materials experimented with for this part and a number of forms of high-strength iron are being used on certain motor vehicles. There is no question that the resistance to wear or scoring of high-strength cast iron or of specially annealed or heat-treated malleable iron is superior to most any other commonly used brake-drum material. From the standpoint of cracking from severe service, there have been some indications that too high a modulus of elasticity in a cast material is not desirable because when the inside surface of a brake drum heats up during severe service it exerts a certain amount of force in expanding, attempting to enlarge the colder outside layer of the brake drum. The higher the modulus of elasticity of the material, the greater will be the resistance of the outside against this expanding force, and, consequently, the greater will be the compressive effect upon the inner surface of the brake drum. When this compression upon the inner surface exceeds the elastic limit of the material, cracking results due to failure in compression. The ideal combination, therefore, in a material to be used as a brake drum would seem to be a low modulus of elasticity with a high combined carbon and high hardness and strength to resist wear.

A. L. BOEGEHOLD.[10]

TO THE EDITOR:

Mr. Upham's and Mr. Boegehold's discussions are interesting because both discussors represent companies doing a great deal of research work along the lines discussed in the paper.

Mr. Upham asks a question regarding the writing of definite specifications for the newer types of cast iron along the lines adopted by the S.A.E. for steels.

It seems highly desirable that this be done but there seems to be some obstacles which, for the time at least, appear to prevent this being done. It is admittedly true that with the wide divergence of melting and molding methods in vogue, chemical specifications will not truly describe the material sought. It may also be true that physical specifications will not be sufficient unless supplemented by a description of the microstructure. At the present time a number of reputable manufacturers of the materials discussed are doing a splendid job in meeting the engineer's requirements but doing it by entirely different methods. Many of their products are being sold under trade names, which is not so desirable from the engineer's viewpoint. No doubt the next year or two will bring out enough technical information regarding these products so that the materials may be properly grouped and described by some sort of specifications, whether chemical, or physical, or both. It seems desirable that physical specifications should predominate, at least from the foundryman's viewpoint, as that will lead to greater progress in the bettering of the specifications themselves.

R. G. MCELWEE.[11]

Comments on E.C.P.D.

TO THE EDITOR:

I have been much interested in reading the letters[12] of Charles W. Comstock and C. F. Hirshfeld regarding E.C.P.D.

There is much wisdom in Mr. Comstock's contention that we should be careful in our efforts to improve our status by legislation. Any one with common sense will agree that it is practically impossible to formulate any ironclad rules that will classify engineers as they should be classified. Similar remarks would apply to our efforts to accredit colleges. There must be plenty of latitude for the exercise of judgment.

Mr. Comstock rightfully questions our attempts to give credit to or rate engineering work. I would again apply his questions to advanced degrees and publications. In any case there are decisions that are correct and others that are incorrect.

However, the fact that there will always be injustices does not mean that we should give up all efforts to improve the status of the entire profession and coordinate the work of its component societies. Those of us who have anything to do with the formulation or application of these rules must use our good old "common sense." Regardless of profession, there is plenty of need for common sense and balance in our efforts to improve the present social system.

There has been and will be much over-lapping and duplication as has been aptly shown by Professor Croft.[13] Those of us who feel the necessity of belonging to several of the national societies are aware of this fact. However, I doubt if the suggested reorganization would result in sufficient saving to justify its disruptive effect at this stage of the game. We certainly need no more societies.

---

[10] Metallurgist, General Motors Research Division, Detroit, Mich.

[11] General Manager, Ecorse Foundry Company, Ecorse, Detroit, Mich.

[12] MECHANICAL ENGINEERING, July, 1935, pp. 450–451.

While I do not feel that we should restrict ourselves to the field of "psychic interest," I think this field should receive the major part of our attention. "Material interest" should not receive as much attention as the furtherance of scientific and technical advancement.

CARROLL D. BILLMYER.[14]

National Apprenticeship

TO THE EDITOR:

Ten years ago Harold Falk, of Milwaukee, advocated a national apprenticeship organization in a paper[15] which he presented before The American Society of Mechanical Engineers. Mr. Falk probably did not contemplate a public, federal plan of national apprenticeship; it is more probable that he hoped for national apprenticeship under private auspices. In any case, national apprenticeship is here, is under federal direction, and has made a successful beginning. Neither did Mr. Falk think then that the first executive secretary of a national apprenticeship organization would be one who was at that time a young deputy supervisor of apprenticeship in the state of Wisconsin and who frequently visited his plant in the interest of the young men who were learning trades there.

As Mr. Patterson has stated in his paper,[16] employers were at first fearful of a federal apprenticeship project. This was natural enough. Employers have not been altogether happy in their experience with various government agencies. However, the Federal Apprenticeship Committee's way of doing business has dissipated these fears to a large degree.

Moreover, one cannot escape the feeling that employers have nothing to complain about. In spite of the hard work of an enthusiastic but small minority, manufacturers have, on the whole, done nothing whatever to train the skilled men who are required in industry. As a result, there is evidence today of a distinct shortage of skilled men although millions are still unemployed. Ordinarily, the government does not undertake an activity of this kind until private enterprise has failed utterly to solve a pressing problem.

The federal plan of apprenticeship has this advantage over private direction that it inspires confidence. Any parents who take their function seriously are much concerned about their sons' vocation, what kind of occupation is best suited to their talents and will make them happiest, and how they can best prepare for the chosen field of work. The kind of parents whose boys make the best apprentices are the kind who will choose the plant in which to apply for a training course as carefully as any one selects the college in which his son shall study engineering or law or medicine.

There was a time, especially in the smaller manufacturing towns, when the people had implicit confidence in the chief officers of important industries in the community and sought their advice in personal matters. Unfortunately, people no longer implicitly trust the employer. In fact, it has come to such a pass that if an employer announces the institution of an apprentice-training program, a considerable number of people will immediately wonder just how the boys are to be exploited. This refers, of course, to those who are undertaking an apprentice-training program for the first time, as there seems to be no lack of confidence in employers who have carried on successful apprenticeship programs over a period of years.

But people do have confidence in the federal government. They may denounce the Administration or this or that policy of the federal authorities but they do have implicit confidence in that vague but powerful entity called "The Government." As a result, the federal stamp of approval on the apprentice-training program of an employer will convince people that his project is legitimate and they will entrust to the employer their sons and their sons' preparation for a career without the slightest misgiving.

Even after the employer has secured federal approval of his training program it is still necessary for him to maintain public confidence by certain obvious precautions. The number of apprentices must be carefully gaged so that the graduates shall not exceed the normal requirement for skilled men in the plant and in the community. A large number of dissatisfied and unemployed apprentice graduates in a locality, except in times of serious general unemployment, will destroy any apprenticeship organization.

Again, the training program must be continuously operated, in good times and in hard times. People justly expect any institution which pretends to prepare young people for life to be permanent and stable. The question may be asked how can apprenticeship training be carried on during a depression. The answer is simply that it must be and a way can be found. The best proof that it can be done is the fact that many manufacturers who are sincere about their apprenticeship have actually continued training programs even when their plants were all but shut down.

The national apprenticeship plan under federal auspices should provide the needed coordination and stimulus and even employers who are most skeptical about government control in industry will probably find nothing in the plan nor its operation to excite their suspicion.

CLEMENT J. FREUND.[17]

---

[13] "The Engineer and His Societies," by Huber O. Croft, MECHANICAL ENGINEERING, July, 1935, pp. 431–433.

[14] Assistant Professor of Engineering and Superintendent of Construction, Rhode Island State College, Kingston, R. I. Mem. A.S.M.E.

[15] "A National Apprenticeship Program," by Harold S. Falk, MECHANICAL ENGINEERING, vol. 47, no. 5, May, 1925, pp. 416–418.

[16] "National Apprenticeship Under Way," by William F. Patterson, MECHANICAL ENGINEERING, vol. 57, no. 7, July, 1935, pp. 420–421.

[17] Dean, College of Engineering, University of Detroit, Detroit, Mich. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of June 28, 1935, and approved by the Council.

CASE NO. 791 (REOPENED)

(Interpretation of Par. P-299)

Inquiry: Par. P-299 of the Code requires that valves and fittings on water lines below the water line shall be equal at least to the requirements of the American Standards for a pressure 25 per cent in excess of the maximum allowable working pressure. This would apparently limit the use of the present 250-lb standard valves and fittings to 200-lb maximum allowable working pressure and also require a valve with a pressure rating of 313 lb to be used for 250-lb maximum allowable working pressure. Since there are no tables giving flange and body thicknesses for cast-iron valves and fittings over 250-lb pressure, will it be permissible to increase the flange and body thicknesses to permit the use of cast-iron valves and fittings on water lines below the water line, up through 250-lb maximum allowable working pressure?

Reply: It is the opinion of the Committee that the present 250-lb cast-iron flange and fitting standards should not be used for the purpose described for maximum allowable working pressures exceeding 200 lb per sq in. This also includes the valves and fittings for blowoffs.

CASE NO. 805

(Special Ruling)

Inquiry: Under the Unfired Pressure-Vessel Code, is it permissible to use so-called slip-on welded flanges, made by fitting either a plain ring or a hubbed flange, machined on the inside to a close fit, over the end of the shell or nozzle neck and welding it thereto to form in effect a double-fillet lapwelded joint?

Reply: It is the opinion of the Committee that the types of flange described above and shown in Fig. 30*A* and *B*, will be permissible for use on vessels constructed in accordance with Pars. U-69 and U-70 provided:

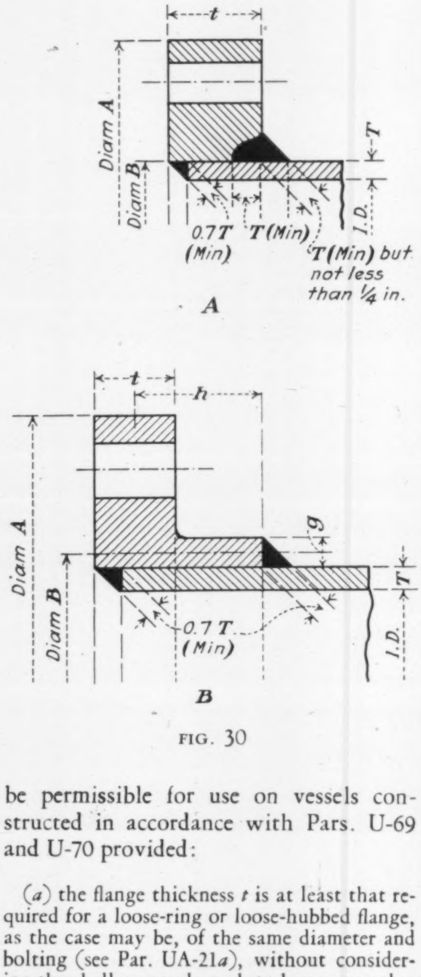


FIG. 30

(*a*) the flange thickness *t* is at least that required for a loose-ring or loose-hubbed flange, as the case may be, of the same diameter and bolting (see Par. UA-21*a*), without considering the shell or nozzle neck to have any value as a hub;

(*b*) none of the following limits are exceeded: working pressure of 300 lb per sq in., working temperature of 700 F, required thickness of shell or nozzle neck of $^5/_8$ in., and ratio of inside diameter to thickness of shell or nozzle neck of 300;

(*c*) the welds attaching the flange to the shell or nozzle neck have dimensions not less than those shown in Fig. 30*A* and *B*, where *T* is the actual thickness of the shell or nozzle neck; and

(*d*) the flange is slipped over the shell or nozzle neck for its full thickness minus the amount required for the weld at the flange face.

CASE NO. 806

(Interpretation of Pars. P-103 and U-71)

Inquiry: Pars. P-103 and U-71 of the Code do not include a specification for forgings. Will forged-steel nozzles conforming to the chemical and physical properties of Specification S-10, Class B, carbon content 0.35 per cent maximum, meet the requirements of the Code?

Reply: It is the opinion of the Committee that if the material for forgings to be attached to boiler or pressure-vessel shells by fusion welding complies with Specification S-10, Class B, the intent of the Code requirements will be met.

CASE NO. 807

(Special Ruling)

Inquiry: At a recent meeting of A.S.T.M. Committee A-1, it was voted to approve certain modifications in Specification A 149-33T (A.S.M.E. Boiler Code Specification S-26), waiving the heat-treatment requirement and adding a lower tensile-grade material. Pending final action by A.S.T.M., will these modifications be acceptable under the Code?

Reply: Pending final action by the A.S.T.M. on proposed revisions of Specification A 149-33T, the Boiler Code Committee approves the following modifications to Specification S-26:

Par. 3*a*, *b*, and *c* may be waived.

Par. 7*a* Introduce a Grade *A* with a tensile-strength range of 65,000/77,000 lb per sq in. Designate 70,000/82,000-lb tensile range as Grade *B*. Elongation requirements for both Grades *A* and *B* $\frac{1,550,000}{TS}$ for flange quality and $\frac{1,600,000}{TS}$ for firebox quality.

Par. 7*b* Maximum tensile strength 79,000 and 84,000 lb per sq in. for Grades *A* and *B*, respectively.

Par. 8 Minimum elongation shall be 18 and 19 per cent for flange and firebox qualities, respectively.

Par. 9 Change table under Pin Diameter Specimen Thickness Ratio to read:

Grade A	*Grade B*
$1^1/_2$	2
2	2
2	$2^1/_2$

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

John Hays Hammond

Autobiography of John Hays Hammond. Farrar & Rinehart, Inc., New York, 1935. 2 vols., 6 × 9 in., 813 pp., photographs, bibliography, $5.

Reviewed by Joseph W. Roe[1]

WHAT a life! What a book! These two volumes should be read by all engineers, particularly the technicians who live and think only within their own profession. The book is more than the record of the life of a great engineer, it unfolds a vivid tale of adventure, of struggles, success, and far-reaching influence in many countries and five continents. Only Herbert Hoover could tell such a tale, and even his story would not be so colorful.

Hammond was fortunate in his family and education. His father was a West Pointer and an army officer who served with distinction in the Mexican War. At its close he was ordered to California and arrived in San Francisco on April 1, 1849, the spring before Marshall's discovery of gold on Sutter's Creek. He was therefore on the ground before even the Forty-Niners. He soon resigned from the army and became one of the leaders in the pioneer life of California, a friend and intimate of all those who helped to make its early history. He married in 1854, and John Hays Hammond was born in 1855.

Hammond grew up in the atmosphere of prospectors and mining, and panned gold for fun when he was playing around the mines. He had the best education obtainable in California at that time and then went to New Haven and was graduated from the Sheffield Scientific School at Yale University. He chose the "Select Course" which covered general science, with little, if any, engineering and no mining. His career at Yale was full of fun, "a pleasant mélange of books, professors, comradeships, social diversions, and athletics." He was never very good nor very bad. As with many others, the chief impression made upon him was not by his studies but by the personalities of some of his teachers, whose friendship he carried through life. At graduation in 1876 he had definitely made up his mind to become a mining engineer, and he therefore went to Germany and studied three years at Freiberg, the foremost school of mining engineering in the world at that time.

On leaving Freiberg he returned to California in the autumn of 1879. At first his technical training was an actual handicap, but he was no stranger to frontier life and wisely kept Freiberg in the background. It was not many years before his superiority over the "practical miners" became so evident that no apologies were necessary. It is not possible in the brief space of a review to outline his steady rise. The story of his early experiences in California, Nevada, Old Mexico, and Idaho, reads like a thriller. It is full of bad men, gunplay, lurid litigation, and Mexican revolution.

With the widening of his interests he opened an office in New York. Early in the 1890's he had had offers to go to South Africa but had declined them; but in 1893 while in England reporting to a board of directors, Barney Barnato renewed his offer. Hammond doubled it and Barnato agreed to it without a word. He went to South Africa and was with Barnato for about a year, when he resigned because Barnato would not follow his recommendations. The separation was friendly, and they remained on good terms until Barnato's death. In fact, Barnato put up $100,000 bail for Hammond at the time of the Jameson Raid, and scolded him for not jumping the bail.

When Hammond's resignation became known, he received a telegram from Cecil Rhodes to come and see him. Hammond was immediately engaged at an increased salary and participation in profits. Hammond was authorized to represent Rhodes and had full authority to go ahead in any way, provided he kept Rhodes informed and received no protest. Hammond became his close intimate with full knowledge of both his financial and political plans. Few could give a better picture of Rhodes' dreams than one sees in the chapters on "The Empire Builder" and the "Winning of Rhodesia."

Perhaps Hammond's greatest professional triumph was the development of the "deep level" mines. The vein at the Rand has a very heavy dip, something in the order of 60 deg. All the mines then operating were "outcrop mines" worked from the surface, and the deepest workings at that time were about 500 ft down. Hammond told Rhodes that in his opinion the vein and its values held down at least several thousand feet and that the property beyond the existing claims, then only farm land, could be bought up and mined as profitably as the existing claims. This involved working at depths of approximately 5000 ft. Aside from the geological gamble there was a serious question among engineers as to whether mines could be worked at such a depth. Rhodes staked his fortune on Hammond's judgment, sold out the holdings of the Consolidated Gold Fields in the existing mines, and utilized the capital raised to buy the new property and develop deep-level mines. It was a tremendous undertaking involving vast expenditure, not only before a cent could be returned, but before success could even be assured. It was a triumph for Hammond that the veins were picked up within a few days of the time, and a few feet of the location, which he had predicted, and these deep-level mines were a complete success.

The reform movement of the Uitlanders and the Jameson Raid are matters of general history. Hammond draws a picture of how it was forced upon them by the reactionary and oppressive policies of Oom Paul Kruger and the small group about him. The whole movement was ruined by the precipitateness of Jameson in entering the Transvaal before the plans were ready. The revolt failed and Hammond, with three others, was placed on trial for his life. The first volume closes with Hammond standing in the dock in the crowded, sweltering court-room in Pretoria, with the judge in black cap pronouncing the words, "That you be hanged by the neck until you are dead. May Almighty God have mercy on your soul."

The second volume is not so vivid as the first. From the crisis in the last lines of the first volume the light begins to break and he comes out more and more into the sunshine of success and honor. His sentence was commuted to imprisonment, then he and the others were pardoned on payment of smashing fines, and as soon as he could close up his affairs he left South Africa permanently, except for several visits.

---

[1] Professor of Industrial Engineering, College of Engineering, New York University, New York, N. Y. Mem. A.S.M.E.

At a great dinner in New York only a few weeks ago, gathered to do Hammond honor, Charles M. Schwab, in presenting him with a medal turned to the audience and said, "You people don't know how lucky you are to see Jack Hammond here. If I had been old Paul Kruger I would have shot him." Hammond's reply was, "If Charlie Schwab had been old Paul Kruger I wouldn't have been a revolutionist."

The next few years were centered in London. Hammond was now a world figure and his life there brought him into contact with the captains and the kings and the great of every country. He tells of work in Russia and of his friendship with Count Witte, and meetings with the Czar and many others. At the end of 1899, after an absence of seven crowded years, Hammond had returned to New York and become consulting engineer for the Guggenheim Exploration Company, a position which he held for five years, and an association most satisfactory to him throughout.

He had been in active service for a quarter of a century, his health was not strong, and he felt that he had earned the right to some leisure, and to do various things which appealed to him. He built a beautiful home in Washington and another in Gloucester, Mass., and for 25 years he has not only enjoyed his success but utilized its possibilities and influence for public service.

The book is not only a record of a great engineer, but of a distinguished American and world citizen. Hammond's professional work developed immeasurably the resources of his own country and many others. His influence in later life has been more personal than public. One of the most striking characteristics which comes out all through the book is his capacity for friendship. Old characters whom he met in the rough days out West keep turning up, and we have intimate pictures of men who have influenced public life in many ways all over the world, Barnato, Rhodes, Oom Paul Kruger, John Hays, Count Witte, Porfirio Diaz, Taft, and Theodore Roosevelt, and all the Presidents and other leaders in Washington since their time. He was active with Carnegie in the cause of world peace, and for years a most effective leader in the Boys' Club work throughout the whole United States.

This is a good book for a young man to read, a story full of humor and absorbing interest, of a brilliant engineer, a straight shooter, who has won success honorably and carries it happily. May he live long and give us another volume.

Research

RESEARCH.—THE PATHFINDER OF SCIENCE AND INDUSTRY. By T. A. Boyd. D. Appleton-Century Company, Inc., New York. 1935. Cloth, $5^1/_4 \times 7^3/_4$ in. 319 pp., $2.50.

REVIEWED BY A. A. POTTER[2]

THIS book discusses in a clear and understandable style the meaning and purpose of research, as well as the qualifications and preparation needed by those who expect to become searchers of new knowledge. This subject is treated under six headings, which are designated as, orientation, method, men, qualifications, achievement, and miscellaneous.

In the foreword the author states that "only a few miles apart were born two of the world's great explorers, Christopher Columbus and Leonardo da Vinci. Columbus typifies the geographic explorer, Leonardo the scientific explorer." While geographic exploration, which is concerned with "that which is" is fast drawing to a close, because the world has now been thoroughly explored, the pioneering of today is scientific in character and projects forward to "that which can be."

Research is not concerned with things as they are. The difference between testing and research is that the testing laboratory deals merely with that which is already in existence, while the research laboratory is concerned about that which could exist if only there were enough imagination and knowledge to bring it into being. Research is a search for new knowledge, under carefully controlled conditions, but is not the gathering of information about an already established product. While the author feels that no line of demarcation can be drawn between pure and applied research, it is generally understood that the objective of pure science research is to advance human knowledge, while the purpose of applied research is either to convert already discovered truth into practical use, or else to discover new facts and to apply them in a practical way.

Part 2 is concerned with the ways in which research is done. The evolution of experimental technique is illustrated by the development of the gasoline automobile, which "came into being as an assemblage of a great many prior inventions and discoveries," the most important of which are given as the method of kindling a fire, the invention of the wheel, the discovery of how to vulcanize rubber, the invention of the internal-combustion engine, and the discovery of petroleum. "To keep on making the automobile constantly better and better," more and more use has to be made of the "pioneering form of research." The author states that the present outstanding needs of the automobile industry are cheaper light metals, a better understanding of the fundamental basis of lubrication, and more knowledge about the behavior of the mixture of fuel and air within the combustion cylinder.

Before 1900 the detached investigator made most of the scientific and practical advancement. At present either the "departmental," the "cell," or a combination of these two systems is found in industrial-research laboratories. While organized research does away with the evils of haphazard experimentation the author points out that the best laboratory has only a minimum of formal organization; also that the mere possession of completely equipped laboratories is of itself no sign that great research will be produced.

The success of the investigator depends upon his ingenuity at developing or adapting from others precise means of supplementing his own imperfect physical senses. New developments of any consequence must consist of the combined contributions of many workers of various talents rather than being the exclusive product of one brilliant person. Among the most essential qualifications of research workers may be included youth, curiosity, imagination, experimentalism, enthusiasm, patience, persistence, faith, courage, common sense, honesty, and modesty.

Part 5, which is devoted to research achievement, is particularly interesting as the contributions of research to human happiness are clearly pointed out; the dividends which come from research are economic, educational, and humanitarian. The author lists among the possible services which research can render the finding of new products, lowering costs, finding uses for by-products, and supplementing failing resources. From the viewpoint of employment that research project is most helpful which establishes new industries or extends old industries.

As Charles F. Kettering has pointed out "the selling of new ideas is even more important than the getting of the idea."

---

[2] Dean, Schools of Engineering, Purdue University, Lafayette, Ind. Past-President, A.S.M.E.

Thus the interpretation of the findings of the laboratory is important, as there is always opposition to the new. However, research publicity must not give misleading information or the impression that new knowledge is developed by mysterious or magical means.

The author has been an active research worker since 1918 and has had an important part in the perfection of ethyl gasoline. Accordingly, his book represents knowledge acquired at first hand.

Corporate Profits

CORPORATE PROFITS AS SHOWN BY AUDIT REPORTS, by W. A. Paton. National Bureau of Economic Research, New York, N. Y., 1935. Cloth, 6 × 9 in., 151 pp., 8 tables, 5 charts, $1.25.

REVIEWED BY E. DILLON SMITH[3]

THIS book is interesting not only for its analysis of corporate profits as shown by audit reports, but because it appears to be the first step in the utilization, for the purpose of statistical research, of the information which reposes in the files of public accountants. The potential value of such a study has long been realized. It is of real significance that such a study as this has been made without any breach of confidence that the corporation places in the accountant. This book offers to management another standard of measurement, wherein an executive can compare his balance sheet and income statement for determining the success or failure of his methods relative to those of a much larger group in the same industry. The author, W. A. Paton, is professor of accounting in the University of Michigan.

The material for the book was based upon the income statement and balance sheet of 714 corporations for the three years 1927–1929. The classification of the corporations was into six major groups, extraction 37 companies; construction 23; manufacturing 350; trading 226; real estate and finance 24; and service 57 companies. The average corporate size was about $2,250,000 in terms of net book assets (total book assets less accrued depreciation and other valuation reserves). The average rate of earnings on this basis was greater than 8 per cent, and fairly stable from year to year.

The manufacturing corporations were more profitable than the other groups. The average rate of earnings for manufacturing was in excess of 9 per cent, while for trading it was only slightly above 6 per cent. Evidence is presented that the years 1927–1928 were more profitable than 1929. It is also of significance to note that those concerns with assets between $50,000 and $200,000 earned a higher rate of return on total assets than did smaller and larger corporations during the same period. The average amount of net assets covered by liabilities was less than 30 per cent. The type of stock outstanding seemed to have no bearing on the amount of liabilities relative to net assets.

Dividend payments on common stock were generally irregular; 37 per cent of the corporations paid no dividends during 1927–1929, 9 per cent paid in one year only, 14 per cent in two years only, and only 40 per cent paid throughout the whole period studied.

The median ratio of current assets to current liabilities among manufacturing corporations included in the sample was about 4 to 1, while for trading it was about 3 to 1. Inventories constituted 26 per cent of the net book assets of the manufacturing group.

This book (No. 28) should be studied after, or in conjunction with, "Industrial Profits in the United States," by R. C. Epstein (No. 26), which was reviewed in MECHANICAL ENGINEERING for March, 1935. The author's conclusions support those of Professor Epstein, even though the basic data are from different sources.

Books Received in Library

AERODYNAMIC THEORY, a General Review of Progress Under a Grant of the Guggenheim Fund for the Promotion of Aeronautics. Vol. III, Div. F-I. By W. F. Durand. Julius Springer, Berlin, 1935. Cloth, 6 × 9 in., 354 pp., illus., diagrams, charts, tables, 20 rm. This is the third volume of the valuable survey of aerodynamic theory sponsored by the Guggenheim Fund, and planned to provide the student and designer with the background theory which is required. In the present instalment the theory of single burbling is treated by Professors C. Witoszynski and M. J. Thompson, the mechanics of viscous fluids by Professor L. Prandtl, the mechanics of compressible fluids by Professors G. I. Taylor and J. W. Maccoll, and experimental methods, wind tunnels, by A. Toussaint and E. Jacobs.

AERODYNAMIK. Vol. 2. Theorie der Luftkräfte. By R. Fuchs, L. Hopf, and F. Seewald. Second edition. Julius Springer, Berlin, 1935. Cloth, 6 × 10 in., 310 pp., illus., diagrams, charts, tables, 30 rm. The present volume of this treatise is a revision and enlargement of part one of the first edition, in which recent advances in practice and results of research work have been incorporated. The author discusses the theoretical principles of aviation and attempts to present the results in a form for direct application to aircraft design.

AIRCRAFT YEAR BOOK for 1935. Vol. 17. Compiled and published by the Aeronautical Chamber of Commerce of America, Inc., 1935. Cloth, 6 × 9 in., 528 pp., illus., diagrams, tables, $3.50. The latest volume of this annual review of developments in American aviation covers its field satisfactorily. Happenings in military and commercial aviation, governmental activities related to flying, notable flights, private flying, airport advances, engineering developments, and other matters of interest are reported, together with many statistical data, sporting records, etc.

CHROMIUM STEELS. Great Britain, Department of Scientific and Industrial Research. By R. H. Greaves. His Majesty's Stationery Office, London; British Library of Information, New York, 1935. Cloth, 6 × 10 in., 321 pp., illus., diagrams, charts, tables, $2.15. This volume provides a detailed account of the history, constitution, and mechanical and physical properties of the plain chromium steels, with a short description of their principal uses. There are several bibliographies, the literature being reviewed to the end of 1933. The volume was prepared for the Department of Scientific and Industrial Research, Great Britain.

CONTRACTS IN ENGINEERING, the Interpretation and Writing of Engineering-Commercial Agreements. By J. I. Tucker. Third edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 10 in., 341 pp., tables, $4. The principles of law which are common to all branches of legal procedure are presented and their applications in engineering and business affairs are discussed, especially in relation to contracts. In the present edition, the chapter on writing engineering contracts has been revised and a chapter added on evidence.

ELECTRIC ELEVATORS, Their Design, Construction, Operation, and Maintenance. By F. A. Annett. Second edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 495 pp., illus., diagrams, charts, tables, 6 × 9 in., cloth, $5. The design and construction of various types of elevators and equipment, and sound methods of inspection, maintenance, and repair are presented in a practical way in this work. The new edition has been greatly enlarged by the addition of new developments, including double-deck cars, two cars in one hoistway, control and signal systems, and automatic landing.

ELEMENTS OF STRENGTH OF MATERIALS. By S. Timoshenko and G. H. MacCullough. D. Van Nostrand Co., New York, 1935. Cloth, 6 × 9 in., 350 pp., illus., diagrams, charts, tables, $3.25. This is an abridgement of Timoshenko's "Strength of Materials," designed primarily as a textbook for undergraduate courses in engineering schools. While the principal features of the larger work are retained, the material has been rearranged and to some extent rewritten to conform to American methods and preferences. Numerous problems are included.

ENGINEERING SHOP PRACTICE. Vol. 2. By O. W. Boston. John Wiley & Sons, New York, 1935. Cloth, 6 × 9 in., 485 pp., illus., diagrams, charts, tables, $5. The description of the basic processes of metal working given in volume one of this work is continued in the second volume by consideration of production machines, some of which combine several basic processes. Turret lathes, screw machines, automatic turning machines, broaching, gear manufacture, grinding, polishing, lapping, punches, dies, presses, die casting, cutting fluids, measuring instruments, and gages are considered. A large amount of information on methods and machines is presented in convenient form for use by students and those in charge of production and design.

---

[3] Chairman, A.S.M.E. Committee on Statistics in Industry. Department of Mechanical Engineering, School of Technology, The College of the City of New York, New York.

Fundamentals of Industrial Marketing. By R. F. Elder. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 317 pp., illus., diagrams, charts, maps, tables, $3. This volume, according to its preface, is the first attempt to present comprehensively the problems connected with the marketing of goods which are used in the course of manufacture or trade. Fundamental principles of marketing, the experiences of concerns engaged in it, and important articles have been brought together systematically. The treatment discusses sales planning, budgetary control, engineering service, and other topics.

Introduction to Physical Science. By C. W. Miller. Second edition. John Wiley & Sons, New York, 1935. Cloth, 409 pp., illus., diagrams, charts, tables, $3. An introductory text for college students which aims to give the necessary fundamental training combined with the broader outlook of modern physics. The author has endeavored to lead the student by natural steps from the beginnings of scientific thought to the results of recent research. Only common mathematics is used. The new edition has been revised to include late discoveries in nuclear physics.

Le Macchine Termiche. Part 1. Apparecchi Evaporatori (Caldaie), Accumulatori e Condensatori. By M. Medici. Casa Editrice Dott. Antonio Milani, Padova, 1935. Cloth, 7 × 10 in., 210 pp., illus., diagrams, charts, tables, 28 lire. This volume, by a professor in the Higher Institute of Engineering at Padua, forms part of a text upon heat engines and is definitely concerned with steam boilers, accumulators, and condensers. The subject is treated theoretically and descriptively, the usual types of boilers and accessories being discussed and their properties considered. The volume is illustrated with photographs and excellent drawings.

List of Books and Other Sources of Information Regarding Coal and Coal Products. Compiled by F. R. Wadleigh, Cecil Apartments, 1026 15th Street, N.W., Washington, D. C., 1935. Paper, 6 × 9 in., 63 pp., $1. This pamphlet contains an extensive list of books on coal and the coal industry, accompanied by lists of societies, coal commissions, periodicals, government departments and other sources of papers and pamphlets upon these subjects. The bibliography is confined to the English language. The entries, which are classified for convenience, cover the geology, mining, economics, and utilization of coal and its products.

Manual of Gear Design. 2 vols. By Earle Buckingham. *Machinery*, New York, 1935. Cloth, 9 × 11 in., vol. 1, 183 pp.; vol. 2, 168 pp., diagrams, tables; $4.50 cash with order; $4.75 in three payments. These volumes are the first two of a series, issued with the approval of the American Gear Manufacturers' Association, which is intended to provide a complete source of reference for the solution of problems of gear design. Section one consists of the necessary mathematical tables, including Brocot's table of gear ratios, a table of the factors of numbers, and tables of circular measure and of the natural trigonometric functions. The tables of angular functions are to eight places, in hundredths of a degree. The second section covers the design of spur and internal gears. The necessary plane and involute trigonometry is presented with the solution of many general gear problems. Following this, the book discusses the design of spur and internal gear teeth, tooth loads, non-metallic gears, and fine-pitch gears for instruments. The volumes are sold separately.

Metallurgical Spectrum Analysis. (With an atlas of 24 plates in a separate portfolio.) By W. J. Crook. Stanford University Press, California, 1935. Cloth, 9 × 11 in. 82 pp., plates, tables, $12.50. An aim of this work is to show that application of spectrometry to metallurgical investigation can be a practicable undertaking. The author is an engineer and is professor of metallurgy at Stanford University; hence is especially fitted to select the information essential to those who are primarily interested in spectrometry as a tool. The choice of equipment, operating conditions, the reading of spectra, and methods of quantitative analysis are discussed. A bibliography is included as well as tables of arc-spectrum lines. The visual atlas covers two sections of the first-order spectrum of 600 A. each, one with a center of 3100 A., the other of 5300 A. Special plates of the iron spectrum, covering the same regions, are also provided.

Metallurgy. By E. L. Rhead. Sixth edition. Longmans, Green & Co., New York and London, 1935. Cloth, 6 × 9 in., 382 pp., illus., diagrams, charts, tables, $4. The aim of this book is to provide a textbook of moderate size for beginners, in which metallurgical processes are clearly described, with emphasis upon the principles underlying them. First published in 1895; it has been thoroughly revised and partly rewritten, and new sections on pyrometry, metallography, and foundry work have been added.

Phenomenon of Superconductivity. Edited by E. F. Burton. University of Toronto Press, Toronto; University of Chicago Press, Chicago, 1934. Cloth, 6 × 9 in., 112 pp., diagrams, charts, tables, $2.50. This monograph, the joint work of members of the department of physics of Toronto University, is intended as a simple but rather comprehensive statement of the methods of producing and measuring low temperatures and an outline of the main facts of superconductivity. Methods of low-temperature thermometry and of the mechanical production of low temperatures are first described. Following this, the book discusses the variation of electrical resistance with temperature and gives an account of superconducting metals and alloys, the relation of superconductivity to direct and alternating currents, and of changes in other physical properties which may occur at the superconducting temperature. There is a bibliography.

Principles of Physical Metallurgy. By G. E. Doan. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 332 pp., illus., diagrams, charts, tables, $3. This textbook aims to supply a unified account of present-day knowledge of metals and alloys, with special reference to their behavior when operated upon in manufacturing. The physics of metals, metallography, and metal technology are successively discussed, attention being focused upon the principles of the behavior of metals as a whole, not of individual metals or alloys. The volume is a rearrangement and extension of a portion of "The Principles of Metallurgy." by Liddell and Doan.

Scientific Papers and Addresses of the Hon. Sir Charles A. Parsons, with a Memoir by Lord Rayleigh and Appendixes by Hon. G. L. Parsons. University Press, Cambridge (England); Macmillan Co., New York, 1934. Cloth, 7 × 11 in., 260 pp., illus., diagrams, charts, tables, $4.50. This handsome volume, to which Lord Rayleigh has contributed a delightful account of the personality of the eminent engineer, is principally devoted to the steam turbine. Twenty important papers dealing with the author's turbine experiences are presented. Three other papers record his attempts to produce diamonds artificially. Two papers by others describe his auxetophone and his activities in the manufacture of optical glass. A complete list of his published papers is provided.

This Modern World and the Engineer. Edinburgh, Royal Scottish Society of Arts, 1934. Cloth, 6 × 9 in., 140 pp., illus., diagrams, charts, tables, 5s. In 1933 the Keith Lectures before the Royal Scottish Society of Arts took the shape of a symposium on the "trend of modern engineering," to which six eminent engineers, chiefly from the Edinburgh School of Engineering, contributed. Their lectures discuss the achievements and problems of modern engineering in the fields of physics, civil, mechanical, electrical, and chemical engineering, and in mining. A final contribution, by Prof. Henry Briggs, discusses some of the economics and social problems of engineering in general. The volume is a readable, thoughtful contribution on a subject of general interest.

Turbulenz, Physikalische Statistik und Hydrodynamik. By H. Gebelein. Julius Springer, Berlin, 1935. Cloth, 6 × 9 in., 177 pp., diagrams, charts, 14 rm. This book is the result of an investigation of the problem of turbulence, undertaken in 1932 by the author under the direction of Professor Prandtl. The object was to develop or establish theoretical hydrodynamics to include the phenomena of turbulence, by applying the statistical method which has proved so helpful in other branches of physics. The author applies the method to the phenomena of flow, develops general basic statistical equations and a theory, which compares satisfactorily with experimental findings.

Unzulänglichkeiten und Irrtümer der Physik, Abbau und Aufbau. By G. Alliata. Paul Haupt, Bern and Leipzig, 1934. Paper, 6 × 9 in., 99 pp., diagrams, 2.40 rm. The author of this book launches a spirited attack against some commonly accepted theories of physics. The first section of the work discusses the errors and weaknesses which he believes have vitiated modern thought in various fields. The second presents a new theory of natural phenomena.

Werkzeuge und Pressen der Stanzerei. Teil 1, Werkzeuge. By E. Göhre. V.D.I. Verlag, Berlin, 1935. Paper 6 × 8, 36 pp., 62 tables, illus., diagrams, charts, 3.80 rm. This is a concise review of the fundamental principles involved in press-working sheet metals. The present volume discusses cutting, bending, and drawing; and describes wide variety of operations, from simple to complex ones.

WHAT'S GOING ON

This Month's Authors

THE stupendous proportions of the Boulder dam called for equipment of unusual size, including hydraulic turbines of 115,000-hp capacity. As manager and chief engineer of the Hydraulic Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., manufacturers of turbines for this project, W. M. White speaks with authority on some of the design and constructional problems involved in these large units. Dr. White's early practice as a hydraulic engineer was with the New Orleans Drainage Board from 1899 to 1902. For the next nine years he was associated with the I. P. Morris Department of William Cramp & Sons Ship and Engine Building, where he was in charge of the design and construction of large hydroelectric plants, including installations at Niagara Falls. His service with the Allis-Chalmers Manufacturing Company began in 1911. He is a member of the A.S.M.E.

Streamlined trains have given prominence to the Diesel-electric drives that are employed in many of the recent units. At a meeting of the Philadelphia Section of The American Society of Mechanical Engineers this spring, John Dickson, manager of the Diesel-Electric Division of the South Philadelphia Works, Westinghouse Electric and Manufacturing Company, member, A.S.M.E., read the paper on the Diesel engine in rail transportation that is published this month. Mr. Dickson was educated abroad and served his apprenticeship in Glasgow. There he became an engineer and designer of marine-Diesel engines, and later designer and research engineer for William Beardmore & Co., Ltd. He came to this country in 1930.

Karl Arnstein, member, A.S.M.E., who continues this month his description of *The Comet*, high-speed Diesel-electric train for the New Haven road, is the well-known Zeppelin designer employed by the Goodyear Tire and Rubber Company.

At the Semi-Annual Meeting of the A.S.M.E. in Cincinnati, June, 1935, the papers on waste elimination by John Q. Salisbury and T. H. Owens created much comment. Extended abstracts of these papers, appearing in this issue, describe the waste elimination and prevention procedures of the National Cash Register Company, of Dayton, Ohio, and The Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Mr. Salisbury is supervisor of the Machine Tool Division of the National Cash Register Co. Mr. Owens is with the Westinghouse company.

Such a large industrial organization as the Eastman Kodak Company has a great variety of equipment requiring lubrication. Its lubrication practices are therefore of interest to all manufacturers and users of lubricants and to designers and operators of machinery. The authors of the paper in this issue describing the Eastman company's practices are Virgil M. Palmer, superintendent of the industrial economy department, member, A.S.M.E., and Horace F. Smith, lubricating engineer of the company. Readers will recall Mr. Palmer's article on suggestion systems, published several months ago.

A.S.M.E. Aeronautic Meeting, St. Louis, Mo., October 10–12

THE program for the National Aeronautic Meeting of The American Society of Mechanical Engineers, to be held at the Hotel Chase, St. Louis, Mo., October 10–12, 1935, has been announced. The meeting has been arranged by the St. Louis Section of the A.S.M.E. James H. Doolittle, chairman of the A.S.M.E. Aeronautic Division, is in charge of the technical program.

Technical sessions will commence on Thursday afternoon and continue through Saturday morning. The forty papers and addresses are devoted to airplanes, air transport, power plants, instruments and equipment, materials and testing, and miscellaneous subjects.

Following registration on Thursday morning, the Hon. Bernard F. Dickmann, Mayor of St. Louis, will deliver an address of welcome. He will be followed by the Hon. Eugene L. Vidal, Director of Air Commerce, Department of Commerce, Washington, D. C.

On Thursday evening there will be a joint meeting of the St. Louis section of the A.S.M.E. and the Engineers Club of St. Louis at which H. J. E. Reid, of the Langley Aeronautical Memorial Laboratory, Langley Field, Hampton, Va., will speak.

"SPIRIT OF ST. LOUIS" MEDAL TO BE AWARDED

The 1935 National Aeronautic Meeting Banquet, to be held on Friday evening, will be the occasion for the presentation of the "Spirit of St. Louis" medal. This medal, which was endowed by members of the A.S.M.E. and citizens residing in St. Louis, is awarded for "meritorious service in the field of aeronautical engineering." Two awards of the medal have been made. The first, on the occasion of the aeronautic meeting held in St. Louis in 1929, was to Daniel Guggenheim, founder of the Guggenheim Fund for the Promotion of Aeronautics; the second, in 1932, was to Paul Litchfield for his work in encouraging and sponsoring airship design and construction in this country.

SATURDAY AT LAMBERT FIELD

Saturday afternoon will be spent at Lambert Field where an opportunity will be provided to inspect the field and airplane plants. A paper on the air-transport plane of the future will be read by Kendall Perkins, of the Curtiss-Wright Airplane Company, Robertson, Mo. Following the reading of the paper there will be exhibits and flying. A dinner and smoker are scheduled for Saturday evening.

PREPRINTING PAPERS

The St. Louis committee is planning to preprint the papers to be delivered at the meeting in a booklet that will be available at a cost of $1.50 per copy. Orders should be mailed to E. H. Sager, Secretary, A.S.M.E., St. Louis Section, Washington University, St. Louis, Mo.

A detailed program follows:

THURSDAY, OCTOBER 10

9:00–11:00 a.m. Registration

11:00–12:00 a.m. General meeting

Address of welcome, by Hon. Bernard F. Dickman, Mayor of St. Louis.

Introductory talk by Hon. Eugene L. Vidal, Director of Air Commerce, Department of Commerce, Washington, D. C.

12:00–1:30 p.m. Luncheon

1:30 p.m. Airplanes

Rotary Wing Aircraft, by Elliot Daland

Radical Developments in Aviation, by P. E. Hempke

Two-Dimensional Boundary Layer Flows Over Flat and Concave Surfaces, by A. H. Blaisdell

Amphibians, by Alexander Seversky

Stressed Skin Aircraft Construction and Its Influence on Other Engineering Construction, by Carl F. Green

Advantages and Possibilities of Shot-Welded Stainless Steel in Airplane Construction, by Carl De Granahl

Wing and Tail Flutter, Causes, Effects, and Remedies, by W. E. Savage

The Small Privately Owned Airplane and Its Probable Future, by John H. Geisse

1:30 p.m. General

Aviation Schools, by Oliver L. Parks

Airport Management, by Milton D. Girton

Can the Human Body Keep Pace With the Airplane? by David A. Myers

The Physiological Effects of Flight on Pilot and Passengers, by Wade Hampton Miller

The Use of the Airplane in Pipe-Line Inspection, by C. B. McMahan

Airships, by Frank Kennedy

8:15 p.m. Talk at Engineers Club of St. Louis

Joint Meeting of the St. Louis Section, A.S.M.E. and the Engineers Club of St. Louis

Unique Methods and Equipment Used in Aeronautical Research by the National Advisory Committee for Aeronautics, by H. J. E. Reid

FRIDAY, OCTOBER 11

9:30 a.m. Air Transport

Airline Traffic Problems, by Harold Crary
Aeronautical Meteorology and Scheduled Air Transportation, by Paul A. Gareau
Airline Engineering and Maintenance, by L. G. Fritz and W. A. Hamilton
Airline Operation, by C. R. Smith

12:00–1:30 p.m. Luncheon

1:30 p.m. Power-Plant

Large Engine Development, by Harold Caminez
Aircraft Engine Fuels of the Future, by Alford J. Williams
The Lubrication of Aircraft Engines, by Frank J. Philippbar
Diesel Fuel for Aircraft Engines, by T. B. Rendel
Propeller-Crankshaft Vibration Problems, by H. H. Couch
Controllable Pitch Propellers, by Glen T. Lampton
The Military Aircraft of the Future, by Ford Prescott

1:30 p.m. Instruments and Equipment

Measurement of Altitude Under New F.A.I. Rules, by W. H. Brombacher
Radio Shielding, by Roy T. Hurley
"Combating Ice," by Harry E. Waner, M. L. Taylor, R. L. Colley
Recent Radio Developments for Applications to Private Aircraft, by H. N. Willets
Airport Lighting, by Preston Bassett
Rubber in Aircraft Construction, by Larry Guinther
Streamline Tires, by Ray Brown
Aerial Photography, by B. B. Talley

7:00 p.m. 1935 National Aeronautic Meeting Banquet
Presentation of "Spirit of St. Louis" Award

SATURDAY, OCTOBER 12

9:30 a.m. Materials and Testing

Recent Developments in Metallurgy, by J. B. Johnson and R. R. Kennedy
New Methods of Testing Aeronautical Materials and Parts, by D. M. Warner
New Test Methods, by N. L. Mochel

12:00–1:30 p.m. Luncheon

1:30–2:00 p.m. Trip to Lambert Field

2:00 p.m. Session and inspection trip

The Air Transport Plane of the Future, by Kendall Perkins
Exhibits
Flying
Transportation to St. Louis at 6:00 p.m. for those desiring to go

6:00 p.m. Dinner and smoker
Fireworks

A.S.M.E. Annual Meeting Technical Program

FOR the technical program being arranged for the Annual Meeting of The American Society of Mechanical Engineers, to be held December 2–6, 1935, thirty-six technical sessions are being planned. The following Divisions will take an active part: Fuels Division, three sessions; Power Division, three sessions; Railroad Division, two sessions; Applied Mechanics Division, two independent sessions and two joint sessions; Process Industries Division, four sessions; Management Division, four sessions; Machine Shop Practice Division, two sessions; Hydraulic Division, two sessions.

Sessions on education and training, textiles, iron and steel, oil and gas power, petroleum, steam research, safety, wood industries, boiler feedwater, power test codes, and mechanical springs are also being arranged.

The power program is one of the most extensive of any Annual Meeting in recent years. One of the Power Division's sessions on thermodynamics will be held jointly with the Applied Mechanics Division, and will include a paper on the viscosity of water and steam which will give the results of research work on the critical-pressure boiler at Purdue University. Other steam-power sessions include a five-year progress report, a paper on pipe bends, and another on creep of steel in power applications. A third session will cover boiler circulation and the maintenance of condensers.

The Fuels Division sessions include a symposium on zoned and metered air control for underfeed stokers, a paper on electrostatic precipitators for stoker-fired boilers, and two other symposiums, one on the life of various types of furnace bottoms for tapping ash in the molten state, and the other on the selection of coal for underfeed stokers. The Fuels Division will also sponsor a session on radiant heat in furnaces, which is being organized by the Research Committee on Radiant Heat in Boiler Furnaces, of which W. J. Wohlenberg is chairman. The Boiler Feedwater Studies Committee has planned a program of papers on recent research and tests of boiler feedwater and turbine corrosion.

The Oil and Gas Power Division will present papers on operating costs of Diesel-electric generating stations, and on film lubrication theory and engine-bearing design. There will also be the yearly report on oil-engine power costs for the year 1934 which will be formally presented and discussed. This report, which will cover more than 150 plants, will be on sale in the fall.

The Hydraulic sessions will be held jointly with the Power Division of the American Society of Civil Engineers and will discuss cavitation problems, turbines, propeller pumps, and the progress in cavitation research.

The sessions of the Process Industries Division are of special interest this year. The Heat-Transfer Committee of this division will have two sessions on radiant heat and will cooperate with the Fuels Division in a session on radiant heat in boiler furnaces. Two other sessions will contain papers on automatic control of sugar pans, flash drying, and mechanical dust collection.

The Petroleum Division will present papers on heat-recovery design for petroleum refineries, automatic control of refinery operation, and design of vertical oil-storage tanks.

The Textile Division will have a joint session with the Graphic Arts and the Management Divisions. The papers to be presented will be on power application and other mechanical features of textile printing, application of printing inks to textile printing, and "work assignment," which will summarize the report of the study of a group of engineers for the Silk Textile Work Assignment Board.

Information on other technical sessions planned will be given in later issues of MECHANICAL ENGINEERING.

The Machine-Tool Show, in Cleveland, September 11–21

AS announced in August (page 534), The American Society of Mechanical Engineers, through its Machine Shop Practice Division, will sponsor a program of technical papers at the Hotel Statler, Cleveland, September 11 and 12, in connection with the Machine-Tool Show, which will be held under the sponsorship of the National Machine Tool Builders' Association, Cleveland Exposition Hall and Public Auditorium, September 11–21.

It has been announced that more than 235 exhibitors will participate in the Show and will display a wide variety of machines, machine tools, accessories, and lubricants. About $5^1/_2$ acres of exhibit area, the entire available space in the Exposition Hall, will be filled.

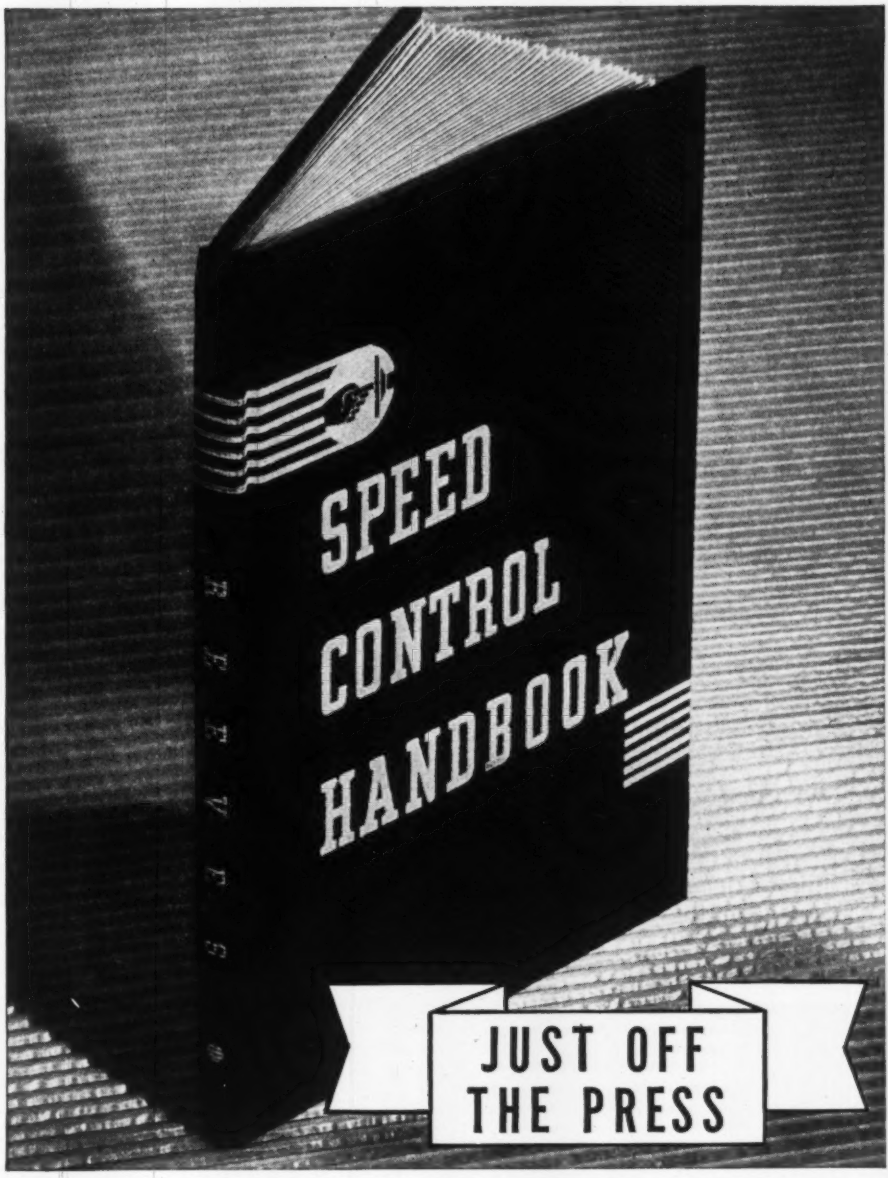
The Show will be the first since 1929, and is expected to be about 50 per cent larger. Improvements in machine-tool design, precision, and capacity will be demonstrated in the machines and equipment that have been developed during the depression period, many of which will be on display for the first time.

In connection with the Show technical papers, presented under the auspices of several engineering societies, have been scheduled for several evenings. The papers sponsored by the A.S.M.E. Machine Shop Practice Division, announced last month, will be presented on Wednesday and Thursday evenings, September 11 and 12, in the Hotel Statler ballroom, the Thursday program including an informal dinner.

On Friday evening the American Society of Tool Engineers will sponsor a program including an informal dinner, in the ballroom of the Hotel Statler. The technical program for Monday and Tuesday evenings, September 16 and 17, is to be under the direction of the Cleveland Engineering Society. Monday's paper will be read at the Public Auditorium, Music Hall, and Tuesday's in the rooms of the Cleveland Engineering Society.

A program of five technical papers on production activity, presented in the ballroom of the Hotel Statler under the direction of the Society of Automotive Engineers, is scheduled for Wednesday evening, September 18, while

(*Continued on page 606*)



FREE ON REQUEST

REEVES presents a new reference book on variable speed control—the most complete and helpful book on this subject ever published.

Handy in size and serviceably bound in blue cloth stamped in gold, this new Handbook contains 112 pages and more than 200 illustrations.

Regardless of the type of product you manufacture, this Handbook will be of interest and value to you. It gets right down to the brass tacks of variable speed control—what it is—how it is engineered and applied—and the remarkable advantages it offers. This book is written out of the experience of REEVES engineers in applying infinite speed adjustability to more than 75,000 machines and in assisting over 1100 machine builders to incorporate speed control as standard equipment.

Every production executive, purchasing agent, machine designer and plant superintendent should have a copy. Since this book is being distributed free only to those who request it, we suggest that you fill out and mail the convenient coupon at right.

REEVES VARIABLE SPEED TRANSMISSION

Many NEW FEATURES in this Handbook

Here are a few of many new features that make it important for you to have this Handbook:

- The requirements of modern speed control equipment—a valuable check list to use in selecting the most efficient methods and units.
- Description and pictorial presentation of the complete line of REEVES Speed Control Equipment—designs, controls, speed ratios, sizes—developed to meet the specific requirements of hundreds of machines and manufacturing processes.
- H. P. ratings and speeds stepped up on REEVES Variable Speed Transmissions, providing greater capacity per unit.
- Hydraumatic Control—a new hydraulic automatic control of high sensitivity and positiveness operating from extremely slight indicating movement.
- Improved endless cord V-belt giving greater strength and capacity, longer life, to this vital part.
- New type frame construction enabling easier installation or removal of V-belt and other operating parts.
- Improved electric remote and automatic controls with more compact mounting of control equipment.
- Force-feed lubrication system on open design REEVES Transmissions.
- Complete data on the REEVES Vari-Speed Motor Pulley, the efficient, simplified unit for direct installation on motor shaft.
- Engineering data in convenient form for reference—tables for selecting correct size and class (speed range) of REEVES Transmission for any machine application. Complete dimension diagrams of various REEVES designs, efficiency charts, etc.

USE THIS HANDY COUPON

REEVES PULLEY COMPANY
Columbus, Indiana

Please send FREE copy of your new Speed Control Handbook G-35.

Name ....
Title ....
Company ....
Street ....
City .... *State* ....

on the following evening the Cleveland section of the S.A.E. will sponsor an informal "production" dinner in the Hotel Statler ballroom, after which a technical paper will be read.

Members of The American Society of Mechanical Engineers participating in the Machine Tool Congress and visitors in Cleveland are cordially invited to make use of the facilities of the Cleveland Engineering Society headquarters, which are located at 410 Hanna Building.

Application blanks for reduced-fare certificates will be sent to the entire United States and Canadian membership of the A.S.M.E. but it will be necessary for the individual member who wishes one of these certificates to apply for it, and *no certificate can be obtained unless an application is received.*

Hotel accommodations may also be obtained by applying directly to the headquarters of the National Machine Tool Builders Association, 1220 Guarantee Title Building, in Cleveland. A housing committee has been appointed to take care of these requests and members will be assigned to whichever hotel they may prefer, assuming, of course, that reservations can still be made.

A.E.C. News From Washington

NUMEROUS projects under the work-relief program have been approved over the past month. Now that allocations of funds have been made to operating units and the general organization of the program has taken form in Washington and in the field, the program is developing toward a peak in field operations scheduled for about November. Most of the agencies entering the work-relief picture have fairly well outlined their procedure and have worked out lines of cooperation with other agencies. Much of the apparent delay is now developing into what seems to be better planning, which utilizes experience gained in recent years and should tend to eliminate waste and confusion.

The Works Progress Administration is looking ahead to next winter and is seeking carry-over projects for its employees displaced from construction work by weather conditions. The purpose is to provide continuous work for all relief employees.

Another interesting development is the introduction of RFC into the rural electrification program by way of a reorganized Electric Home and Farm Authority which will loan RFC funds to farmers for electrification of their homes, farms, and cooperative enterprises.

Applications for new non-federal projects are being received by the Public Works Administration under the new plan of 45 per cent federal grant and 55 per cent loan at 3 per cent interest, revised from the 30 per cent grant and 70 per cent loan at 4 per cent formerly in effect. After a project has been approved, 15 per cent of its cost may be made available for plans and surveys.

The Federal Housing Administration has raised its limitation on modernization credit from \$2000 to \$50,000. This lets in jobs big enough to employ engineers. Regulations have been liberalized as to purchase of machinery and equipment.

Region No. 1 of the FHA, which formerly covered only the State of New York, has been extended to include Connecticut and Rhode Island. Julian M. Gerard has been appointed director of the region and Thomas G. Grace for the State of New York. Mr. Gerard formerly was president of the International Germanic Trust Company and has held other banking positions. He was the FHA State Director for New York prior to the reorganization of the district. Mr. Grace was formerly district counsel of the HOLC. Both make their headquarters in New York City.

The newly organized National Youth Administration has announced that its aid to high-school and college students from relief families will take the form of part-time work.

Special surveys planned by the Bureau of the Census may be of interest especially to engineers not physically able to do field work. A census of business during 1935, covering all fields except manufacturing and agriculture; a national survey of retail trade; and an alphabetical index of all individuals included in the Census of 1900 are among the projects recommended.

Survey of Welding Literature

ENGINEERING Foundation has appointed a Welding Research Committee to initiate and conduct a critical review of world welding literature, to render modest aid to worthy individual projects functioning under the Fundamental Research Committee of the American Bureau of Welding, and to sponsor specific research investigations. The project will be started by funds contributed by Engineering Foundation supplemented by funds and services supplied by industry. The project is jointly sponsored by the American Institute of Electrical Engineers and the American Welding Society.

Among the first proposed activities of the committee is a canvass of industry for the purpose of determining what services can be counted upon by the committee in the formulation of a program which will most effectively utilize the total of the resources which will be available to it. These contributed services will doubtless be of various kinds, such as reviews of literature and translations of foreign-language articles which have been or are being made for private purposes; technical assistance, materials, and the loan of apparatus in connection with specific research investigations; and unpublished research data. A maximum of contribution in the form of such services can be made by industry at a minimum of additional cost.

It is also proposed to collect information from which can be prepared a list of research projects now under way and being planned that can be made available to the committee. Suggestions will be solicited for research projects which are recommended for prosecution under cooperative auspices. Another plan being considered is the setting up of a clearing house for translations and abstracts dealing with welding literature so that unnecessary duplication may be avoided and a maximum of cooperation secured in the critical abstracting of such literature.

C. A. Adams, Harvard University, Member, A.S.M.E., is a chairman, and Wm. Spraragen, American Welding Society, Secretary of the Committee. The other members are: J. H. Critchett, Union Carbide & Carbon Research Laboratories; J. J. Crowe, Air Reduction Sales Company; H. M. Hobart, General Electric Company, Member, A.S.M.E.; D. S. Jacobus, Babcock & Wilcox Company, Past-President, A.S.M.E.; G. F. Jenks, Ordnance Department, U. S. Army, Member, A.S.M.E.; and F. T. Llewellyn, United States Steel Corporation. Communications should be addressed to Wm. Spraragen, American Welding Society, 33 West 39th Street, New York, N. Y.

American Scientific Congress in Mexico City, Sept. 8–17

THE American Society of Mechanical Engineers, through the Department of State, has been invited to participate in the Seventh American Scientific Congress, to be held in Mexico City, Mexico, September 8 to 17, 1935. The Congress is divided into fourteen sections of which Section 1, Physics and Mathematical Sciences, Section 3, Engineering, and Section 4, Industrial Chemistry, will be of greatest interest to engineers. Members of the Society are invited to attend the Congress.

Proceedings Available of Fifth Conference of Printing Industries

THE proceedings are now available of the Fifth Conference of Technical Experts of the Printing Industries held on October 8 and 9 in Philadelphia. Copies have already been sent to all members registered in the A.S.M.E. Graphic Arts Division (formerly Printing Industries Division). Those desiring extra copies may secure them from the Society at the cost of \$0.75 a copy. The proceedings contain the following papers:

"The Photomechanics of Color Photography," by Harry A. Groesbeck, Jr., with discussion by Harold Fowler, H. Grant Schleicher, Thomas E. Dalton.

"Synthetic Resins as a Process Roller Material," by A. L. Freedlander, with discussion by W. S. Robinson, E. R. Bridgewater, W. J. Risley, Jr., Walter E. Wines, W. A. Lippincott.

"Rubber Plates for Letter-Press Printing," by Ralph H. Schwarz and J. Homer Winkler.

"Observations on the Technology of Rubber-Plate Manufacture," by W. J. Ruscoe, with discussion by H. W. Haydock, Hylton Swan, E. M. Frankel, Henry Kohlus, J. Gilbert E. Wright, William M. Lee.

"Photochemical Reproduction on Offset Plates," by William C. Huebner, with discussion by Randolph T. Ode, Wells F. Harvey.

"New Developments in Offset Printing," by Burt D. Stevens with discussion by J. Gilbert E. Wright.

(*Continued on page 608*)

SPECIFY SKF for
Machine Tools and
Shop Equipment.

MACHINE TOOL PERFORMANCE DEPENDS ON BEARING ACCURACY

WHEN it's a precision job, it's a job for SKF accuracy. And, obviously, every machine tool job is a precision job. Check up on that statement yourself. You'll find SKF's in grinders, drills, lathes, in all kinds of machine tools.

Yet precision . . . the ability to insure perfect rigidity at all speeds . . . is merely one of SKF's many advantages. For SKF's meet heavy strains and stresses imposed on spindles, speed mechanisms and gears. They avoid chatter, maintain alignment, and keep going smoothly at all times.

Good bearings and good machines always keep company. And though there are many good bearings, there's only one SKF.

SKF INDUSTRIES, INC., Front St. & Erie Ave., Phila., Pa.

3455

SKF

BALL AND ROLLER BEARINGS